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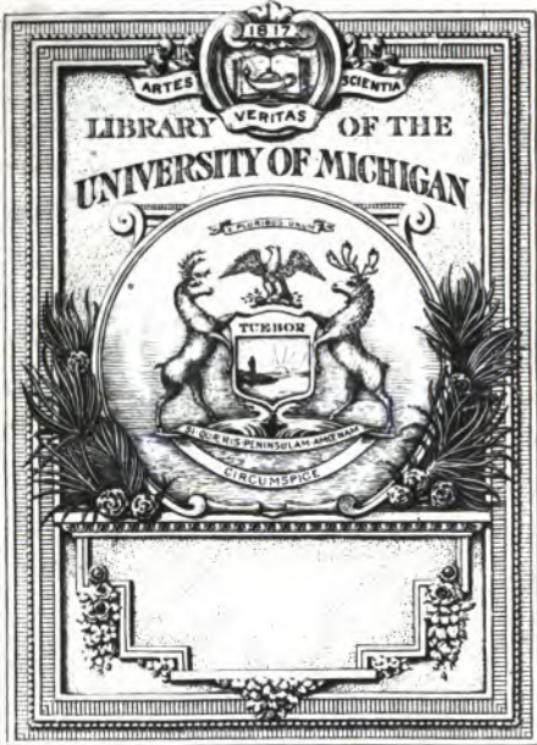
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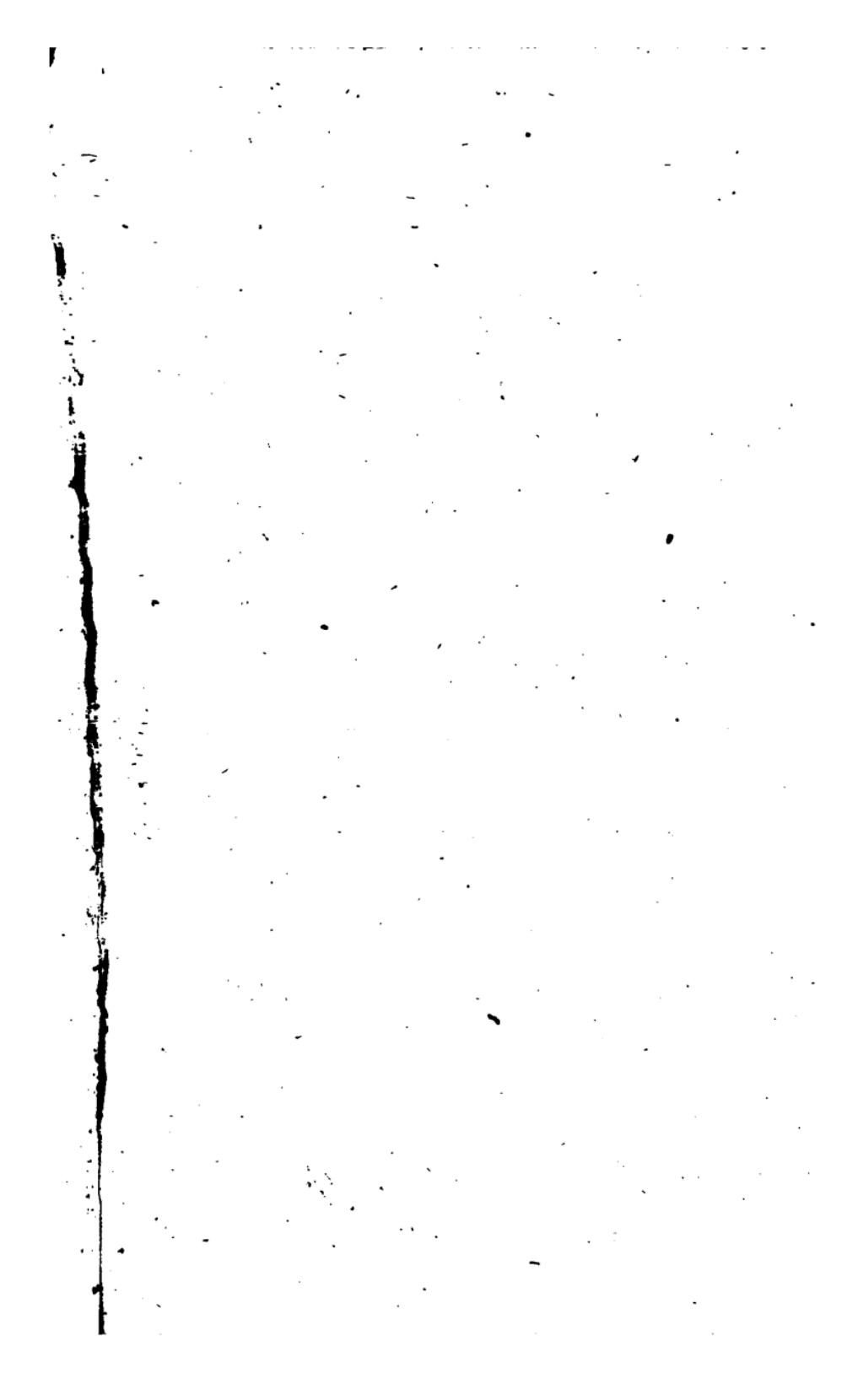
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Frontisp. to 1d. II.



J. Mynde sc.

The Dutch Spying-glass
Applied to Astronomy in the year 1609.

Spectacle de la Nature:
OR,
NATURE DISPLAY'D.
BEING
DISCOURSES
On such PARTICULARS OF
NATURAL HISTORY
As were thought most proper
To EXCITE the CURIOSITY,
AND
Form the MINDS of YOUTH.

Illustrated with COPPER PLATES.

VOL. IV.

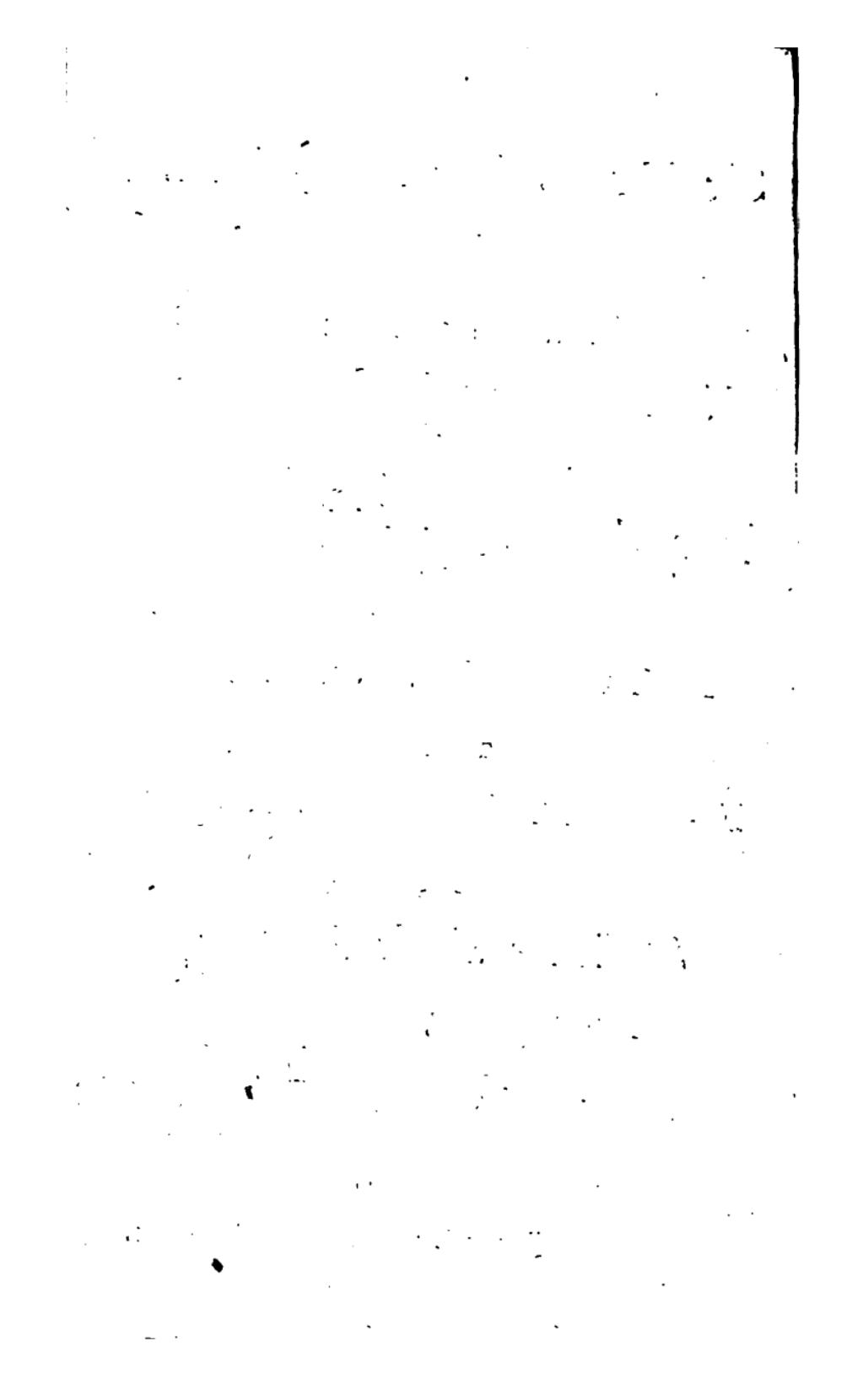
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A

LETTER

FROM THE

PRIOR

TO THE

CHEVALIER.

SIR,

YOU desire me (and from a good Friend such Desires are Commands) First, to pick out for you a Set of choice portable Books fit for a Gentleman of the Sword: Secondly, to send you by Letter the Sequel of our Conversations on the *Spectacle de la Nature*; that Absence, as you are kindly pleased to say, may be no Interruption to your Pleasures. I shall readily, and to the best of my Power, comply with your Desires on both these Heads. Nor can I, indeed, permit myself to refuse so reasonable a Request; and I shall, perhaps, find my own Account in endeavouring to fill up some of your leisure Hours, when you are not engaged in your Exercises and Travels.

A Soldier's Library (especially when he is in Service, or on the Road) neither must nor can consist of many Volumes. A judicious Choice is the chief Merit of his Books, and these may very well be reduced to the three
Vol. IV. B following,

following, *viz.* A New Testament, *Cæsar's Commentaries*, and *Euclid*, not doubting but you will always join to them the *Book of Nature, Mankind*. Such a Library may attend you every where, fill up all the Vacancies, as well as supply the Wants of your Life, and be every Day swelled with new Observations, without multiplying your Incumbrances, or magnifying your Baggage. This is all I can do with Regard to your first Request, and I think it sufficiently answered.

As to the Second, *viz.* To proceed in taking a View of the most beautiful Parts of Nature. As we have already surveyed the internal and external Parts of the Earth, the very Order of Nature itself dictates, that the Heavens, and the Relations the several Parts of the Universe have to our Wants, should be the Matter of our following Discourse.

Spectacle de la Nature.

A

P L A N
OF THE
STUDY of the HEAVENS.

DIALOGUE I.

YOU may remember that when we
some Time since amused ourselves
with examining the several Opera-
tions of little Animals, and the Structure and Frame of
the smallest Plants, you therein discovered a Generation
so regular, so constant, and persevering an Uniformity of
Species, and an Organization so far superior to our li-
mited Understandings, that we both were struck with
Amazement at contemplating the unfathomable Wisdom,
which the Creator has displayed in the minutest and less
perceptible Objects. These Particulars of Natural His-
tory seemed to me at that Time to have had also another
good Effect on you, to have made you inquisitive.

Part I. of Spect.
de la Nat. Vol. I.

DIALOGUE I.

The View we afterwards took of the
 Part II. Vol. 2. Helps we every-where find near at Hand,
 and y. on the Surface, as well as within the
 Bowels of the Earth, made us sensible of

the Dignity of Man. This Inventory of our Possessions and Furniture of all Kinds, raised in us a Surprize at seeing ourselves so very dear to the Creator, and filled us with a thorough Sense of Gratitude, for the Bounties thus heaped upon us, and dispensed to none but ourselves, since we are the only Beings he lets into the Knowledge of their Existence, and to whom he has given the free Use of it.

If we raise our Eyes up from the Earth Part III. Vol. 4. to the Heavens, there we discovek Beauties of a very different Kind. There we receive Presents of far greater Value than all that have been mentioned. But though the shining Stateliness of the Firmament makes it the brightest Part of the whole Scene of Nature; yet we are much less affected and concerned at the Sight of so many magnificent Decorations rolling over our Heads, than we are at the Thought that they all move for our Sake. The Earth, indeed, when compared with that immense Globe of Fire that gives it Light, seems not to be distinguished from the five or six other Planets, which, as well as the Earth, borrow their Light from it, and appear to be so very inconsiderable Objects of Nature. Again, our Globe, compared with the Stars, dwindles to an imperceptible Point. What then shall we think of him, who inhabits it? He indeed, seems to be quite annihilated. Shall we believe, after this, that the Almighty had him in View, when he framed his Works; and that it is for him God has regulated the annual Circle, the Inequality of Nights and Days, and the Vicissitudes of Seasons?

Sure, the Excellency of the Beings God has created is not to be measured with a Fathom. The Inhabitant of the Earth has received an Understanding, a Faculty to will, a Soul. It is this minute Being, whom God admits to that Knowledge of his Works, which he denies to the Sun itself. It is for Man he designs both the Use and the Benefit of this stately Retinue. Man is the only Creature on Earth, whom God invites to praise him for it.

A modest Sense of our Littleness and Insignificancy may doubtless be of great Service to us; but Man is more thankful as well as more surprized, when he sees, with how great Distinction God has been pleased to treat him, and to make him Psal. vii. ver. 5 and 6. here below, the sole Spectator, and the true Enjoyer of Nature. Far, then, from considering his own Meanness, with a stupid Discontent, he, on the contrary, is sensible, that this his Meanness is amply recompensed by the noblest and most valuable Privileges. He cannot bearken to Reason, and not discern that pleasing enchanting Truth; that he is, on Earth, the chief Object of his Creator's Complacency and Concern. Though there were in other Spheres Millions of intelligent Beings, on whom God should think fit to bestow some other Favours (a needless Inquiry, and not within our Reach) would it be less true, that Man on all Sides experiences a gracious bountiful Hand, paternal Cares, and an Order established only for his Sake? What Dignity, what Greatness is it, to have a Father, who, on our Account, strews the whole Earth with Blessings of all Kinds, and even vouchsafes to make the very Heavens subservient to our Interests!

I need not, my dear Chevalier, here insist on the Excellency of the Study of the Heavens, in order to raise your Curiosity. That Science, which points out the Order and Course of the Stars, the Path and Effects of Light, and all the Relations the Earth can have with whatever surrounds it, in short, universal Physicks is, undeniably, of all Sciences that which most elevates the Soul of Man, by the Grandeur of the Objects it offers to his Consideration. It may properly be said to inlarge his Mind, in submitting the very Course of the Stars to his Understanding, and to join with the Merit of doing Mankind many signal Services, that of affording Piety Motives both of a lively Gratitude, and of the most profound Veneration.

You very well guess at all the Beauty of Astronomy, and of the whole Tenor of Natural Philosophy. But it must not hide from you, that these very Sciences, by the false Methods with which they have been pursued, and

the wrong Use they have been put to, have been the Occasion of infinite Mischiefs. They gave Birth to Idolatry, and have filled the World with Prejudices, Superstitions, and idle Fancies. Nay, on this Irreligion itself has more than once attempted to support itself. I therefore stop short at the Consideration, and hesitate on the Choice I am about to make for you; seeing the Advantages to be reaped from these Studies are attended with so great a Number of Errors and Dangers.

Another Obstacle, not much less perplexing, is the Difficulty of letting you into the celestial Motions. It is not with this Part of Nature, as with an Insect, or a fine Flower, the Knowledge of which may be attained at first Sight, or by the Help of a magnifying Glass. I therefore thought the easiest and surest Method was this, *viz.*: To facilitate the Approach of these so numerous and so vast Bodies, by offering them to your Sight under different Aspects, and at several Times, gradually making them easy and familiar to you. Must I then begin with requiring of you a large Stock of Machines and Geometry? No sure; we need not use *Greek* or *Algebraic* Terms, so long as we can understand one another in our usual Speech.

I shall begin with plainly laying before Part I. Vol. 4. you, without any Disputes or mathematical Distinctions, what our Eyes, and the first Appearances, discover to us of the Structure of the World, and what common Sense suggests to us of the Excellency of God's Favours towards us, together with the Usefulness of the Day, and of the celestial Revolutions.

After this, we shall go one Step further. As the Knowledge of the Heavens cannot be attained but by a long Series of Observations, nothing can be more natural, than to add to our own Experience that of Men, who lived before us. I am, therefore, to furnish you with a History of the Progress, which the several Observers of Nature have made therein from one Age to another. But their Works are of two Kinds: They sometimes run upon experimental Truths, sometimes on Hypotheses; by which they endeavour to explain the inward Frame and Structure

ture of each particular Body, or the general Fabric of the Universe, or the Concurrence of those Forces, which put all Nature in Motion. Do not let us confound the History of the Discoveries with the Recital of Hypotheses. We shall begin then with the History of Physicks, or Experimental Philosophy, and of the Uses we have experienced from it. The first Naturalists, whose Discoveries I shall give you an Account of, were, perhaps, neither great Geometricals or great *Calculists*. They were very often Ploughmen, Gardeners, Shepherds, Travellers, or Merchants, who acquainted others with some new and useful Observations. But what they have taught us is certain, and the Benefit of it uncontested. It is but just we should particularly insist on this experimental Philosophy, which makes up the Happiness of Mankind. Hence we shall pass on to the History of general Physicks, which aims at no less than informing us of the Manner in which every Thing had its Original, or at least at determining the Laws and moving Forces which regulate the Course of every Globe. In this we shall find many very great Names, and famous Disputes: From the Exposition of the Hypotheses, you will judge of the Benefit that is to be expected from, and of the Value that is to be set upon them: In both Histories we shall carefully remark the wrong Uses, to which these Sciences have been applied, and prevent the Mistakes and Extravagancies of which this Study might be the Occasion.

You are sensible, my dear Friend, that when I chose this Method, preferable to that of leading you from the geometrical Theory of the World, and the Study of the Motion of the Celestial Bodies, to the Consideration of particular Effects, it was in order to render easy to you the noblest of all Studies, instead of giving you a Disgust to it, by regularly pursuing it with Prolegomena, Axioms, and mathematical Demonstrations.

This Choice of mine is still grounded on the Desire I have of procuring you another far greater Advantage. Your chief Interest, as well as mine, is perfectly to know the Place we inhabit, and the Benefits we there enjoy. Let the Utility and Inutility of general Physicks be what it will (and this will plainly appear from the Comparison

we shall make between that and the Experimental) the chief Good we ought constantly to aim at in both, is to make the Whole subservient to the Knowledge of the Earth. The Study of the several Points, Motions, and Aspects of the Heavens, is not intended to acquaint us with what passes in the Firmament; and we in vain are inquisitive that Way, unless it be to improve our Manners and our Conduct within our own Sphere. But if the Study of the Heavens may be made to refer to us, and have a general Relation to Mankind, it must chiefly be effected by a faithful Account of those Observations, which Necessity has from Time to Time caused People to make on the several Objects which Heaven offers to our View, and of the constant Benefits, which Mankind reap from it. The History of Natural Philosophy is indeed the Enumeration of our Wants, and of those plentiful Supplies which God has placed within our Reach. It is good only as it shews us what is over our Heads, without making us lose Sight of what is under our Feet, and as it engages us to serve our Brethren (that is, all Men without Exception) by a more perfect Knowledge of that Soil we are appointed in common to improve.

I shall therefore endeavour, my dear Chevalier, to lay the History of Natural Philosophy in such Order before your Eyes, that, after having read it, you may have a tolerable Idea of the general Disposition of our Globe, of the Aspects under which the Heaven is seen by the several Climates of the Earth, and of the principal Interests which unite the Inhabitants thereof. In this Science, more than in any other, I should think myself to have led you the best Way, could I have taught you to leave, without Regret, whatever is metaphysical, abstruse, and no ways relating to the Wants of Man; how to make yourself Master of what is certain, practical, and of general Acceptation, of what has a Relation to Objects under our own Management, and of what may contribute to our Happiness, either by keeping us more constantly busied, or chiefly by rendering us more virtuous.

For the same Purpose, I shall, perhaps, The Subject of from the History of Natural Philosophy, the 5th Volume. pass on to the practical Part of it; and if you seem to like these Subjects, and to be

Of the H E A V E N S. 9

be desirous of acquiring a more exact and more particular Knowledge of the Use of Globes, of astronomical and optical Instruments, in the Manner in which we calculate the Years, Months, Lunations, and the whole Order of our Days, of the several Uses we may experience from the Knowledge of Motion, of the Laws of Gravity, of the Spring of the Air and Atmosphere, of the reciprocal Pressures of Fluids, and of the Application of the moving Forces to our several Necessities; in order to satisfy you on all these practical Points, we shall, perhaps, in our following Conversations, have recourse to a few mechanical and geometrical, but at the same Time, so plain and so fruitful Principles, that you will be surprized to find, that the experimental Knowledge of Nature, which is the most engaging and most pleasing of Sciences in all Respects, and the most proper to satisfy any judicious Mind, both by the Usefulness and Variety of its Productions, is at the same Time the easiest to be arrived at, and yet the least cultivated.

The whole Purport of my Plan is, in a small Compass, to join together whatever is certain and useful in natural Knowledge: First, By the Help of our Senses, and by inspecting Nature: Secondly, By the Assistance we receive from the History of what has been from Age to Age discovered or improved: Thirdly and lastly, By the Help of some of the simple Elements of Geometry.

Let us begin the Study of the Heavens by the plain Testimony of our Eyes. The Course and Method of it being pretty much in our Choice, we shall begin by the Night, which darkens every Thing, and then run over what the Day shall successively unveil to our Eyes.

THE NIGHT.

DIALOGUE II.

THE Night is no Being. It is barely the Interruption of the Motion of Light towards our Eyes.

But even Non-entity itself is not unfruitful in God's Hands ; and as he has made all Beings spring out of Nothing, he every Day produces from it, not indeed any new Beings, but wholesome Instructions, and many regular Utilities, in Favour of Man.

The Night, by taking from us the Sight and Use of Nature, in a manner recalls us to that primitive Nothingness from whence we first sprung, or puts us again in that State of Darkness and Imperfection, that preceded the Creation of Light. The Distemper, which weakens our Bodies, makes us the more sensible of the Value of Health ; and the Night, which in some sort annihilates the whole Universe, with regard to us, makes us the more sensible of the inestimable Value of Day-light. But Night is not only designed to set off by its Shades the Beauties of the great Picture of the World, and to inspire us with a greater Humility at the Sight of that Darkness which is natural to us, or with a livelier Sense of Gratitude at the Return of that Light, which is none of our Due. Though the Instructions it affords us were never so useful, yet would it be a sad Thing, should it impoverish us merely for our Improvement. What Night seems to cut off from Life, by daily depriving us for several Hours together of the Use of Light, and of the Sight

The Night affords us Instruction.

Of the N I G H T.

Sight of the Universe, it abundantly makes up to us, by the Rest it then procures.

Man was born to Labour. Such is his Vocation, and Estate. But he cannot undergo his Toil, unless his Blood supplies him continually with an infinitely subtle and active Matter, which sets the Springs of the Brain, and the several Muscles of the Body to work. But the perpetual Waste which is made of that Matter, which with such Swiftneſs answers all his Purposes, would at last throw him into a lingering and consumptive Condition, did he not recruit himself, and make up his Losses, by the Use of new Aliments; and these, again, could neither be digested, nor regularly distributed through the whole Body, was he always in Motion. He must leave off the Work of his Brains, his Hands, or his Feet, that the Head and Spirits, which exhaled from him, may be solely employed in assisting the Functions of the Stomach, during the Inaction of the other Parts of the Body.

But God did not leave the Use and Disposal of that Rest to the Reason and Management of Man. He himself takes care to lull him asleep. He makes Sleeping an agreeable Necessity to him, without either letting him into the Knowledge, or giving him the Government of it. Sleep is an incomprehensible State, of which Man is so far from conceiving the Nature, that he can by no Means either procure it to himself when it comes not of its own Accord, or refuse it when it seizes upon him. God has reserved to himself the Dispensation of that Repose, the Time and Measure of which, he knew, would never be well regulated by human Reason. He has chosen Night as the properest Time, and the best Means to introduce Repose into the World, and to fix the Duration of it.

Night, indeed, in covering all Objects with Darkness, obliges Man to cease from his Works; and in order to refresh him after all his Fatigues, by keeping him inactive, it removes whatever might agitate him too much, or affect him too strongly. It conveys Silence and Darkness every where. It takes from him the Scene of Nature, in order to strip him of the Use of his Senses; and as the one is of no Use without the other, it at once deprives him of both. Who cannot discern, in this great

The Necessity
of Resting.

Regard of Providence for Man, the Cares of a tender Mother, who removes all Noise from the Place where she has laid her Son? She fondly watches over him, in order to secure his Repose.

Night and Sleep are so connected, and the former so properly made to bring on the latter, that whenever we stand in need of Repose, we begin it by procuring a sort of artificial Night to ourselves. We seek some shady lonesome Place, and have Recourse to Curtains and Window-shutters. Our Senses are never unbent but by the Removal of what gives them Agitation; and it is evidently this Service to which Night is commissioned and appointed. But let us consider, for a Moment, with what a discreet Caution it discharges that Duty.

The Usefulness of the gradual coming on of the Night. Night, in serving Man, does not tie him up exactly to any precise Moment. It comes not in a blunt and abrupt Manner to extinguish the Light of the Day, and all on a sudden to rob us of the Sight of those Objects we are intent upon. Far, indeed, from coming upon us unawares in the Midst of our Works or Travels; it advances on the contrary by slow Steps, and only increases and thickens its Darkness by Degrees. It permits us to make an End of what it is our Interest to finish, and does not precipitately deny us the Sight of the Goal we strive to arrive at. It is not till after it has decently told us of the Necessity of taking our Rest, that it finally makes an End of darkening the whole Face of Nature.

During all the Time of Man's Repose, Night, for his Sake, hushes every Noise, keeps off all glaring Lights, and whatever might too strongly affect him. It, indeed, suffers a few Animals, whose grim Aspect might scare him while he is at work, to go forth under Favour of its Darkness, and silently seek their Food in the abandoned Fields. It affords these voracious Creatures Means of coming to clear his Abode of whatever might infest it, and even of taking from him such Things as are by him too carelessly guarded. It permits, however, the Animal that stands Centry by him, to give him Notice of what concerns him, while it imposes Silence on every other Creature. It keeps the Horse, the Ox, and his other Domestic

Domestics fast asleep around him. It disperses the Birds, and sends each of them to his respective Abode. As it comes on, it gradually hushes the Winds that disturbed the Atmosphere. It evidently is commissioned to secars the Lord of Nature his Rest. It causes his Repose to be reverenced every where; the Moment of which is no sooner come, but all Tumult ceases, all Creatures retire, and for several Hours together an universal Silence reigns throughout his Habitation.

Nor yet does Nature's Palace remain wholly void of Light. For as those, who inhabit it, might perchance be inclined to prolong their Works or Journies, during the Night itself, several Flambeaux scattered in the Firmament still guides their Steps: But these Lights, which were granted that they might not be left in a total Darkness, yield but a gentle, and not a very brilliant Light. It would have been neither proper nor just, to supply those that wake with such a Light as might interrupt the Repose of others.

When the Absence of the Moon, or the Thickness of the Air, takes from us the Light we stand in need of, we are always Masters of procuring it to ourselves. We find the Principle of it in the Bowels of Flints, and its Fuel in the Wood, the Oil, the Fat of Animals, the Wax which Bees collect from Flowers, and in the vegetative Tallow * that may be drawn from several Plants. But the nocturnal Light serves us very differently from that of the Sun. The latter invites us, it warms us, it presses us, to send us to work. On the contrary, the Fire we light does not come of its own Accord, but stays for our Orders. Nay, we cannot come at it without

* Green Wax-candle is often made with fat and thick Juice, drawn from several Plants. There are found in the Island of Ceylon, large Forests of Cinnamon-trees, whose thin Bark, and especially that of the Branches, is that sweet-smelling Spice so well known by the Name of *Cinnamom*, and whose Fruit, when strained, yields a greenish sort of Tallow, which is whitened and made into Wax-candles. They find in several Places of *Mississipi* the Tree called *Ciris*; the Seed of which they throw into boiling Water, in order to extract a sort of Oil that swims above it. They skim it off, and let it thicken in Cakes, in order to make Wax-candles of it.

out some Toil, nor keep it without Care. That borrowed Light is always ready to disappear; it seems to be misplaced, and even loth to disturb the Repose of Nature. Man rids himself of this, so soon as it becomes either troublesome or useless to him, and he of Necessity wraps himself again in that beneficial Darkness, which helps him to recruit his Spirits, and recover his Strength with Sleep.

It is not only by its Darkness that Night becomes useful to us: It is again of Service through a Coolness, which, by every where pressing down the Spring of the Air, makes it capable of working with greater Activity in all Bodies, and of communicating a new Vigour, both to the dry Gras, and to the enfeebled Animals. It is in order to preserve this beneficial Cool, that the Moon, in reflecting to us the Light of the Sun, gives it us in such a Degree as has no sensible Heat. In vain would we collect that Light in the Focus of the strongest Burning-glass: It does not even affect the Thermometer when put in the Point that unites its Rays, nor causes there the least Dilatation in the Spirit of Wine, otherwise so susceptible of it: An admirable Caution of the divine Artificer, who has established the Order of the Night, and foreseen whatever would be beneficial in it. He reserves, for that Time, a Light strong enough to remove Darkness,

The Cool of the Night. but at the same Time too weak to alter the Coolness of the Air. He alone knows his own Work: He alone can know the excessive Diminution of a Bundle of Rays,

which he causes to pass from the Body of the Sun to that of the Moon, the Remainder of which are reflected down to us weak, and quite destitute of Heat. It is perfectly needless for us to determine its Degree by Experiments, and long Calculations. It would be so much Philosophy lost, on Account both of its little Use and great Uncertainty. But it is no less easy than it is important for us to discern and praise the infinite Wisdom, whose Measures are so exactly proportioned to our Necessities.

The Spectacle fit of that faint Light, or wholesome Coolness which attends the Return of the Night; he, indeed, sees no more the same Beauties in his Habitation,

Prohibition, and every Thing is left striking and lively there: But as the Night has afforded him his proper Spectacle, the Night, in its Turn, favours him with another, that has Charms peculiar to itself, and of quite another Character.

We cannot doubt, but that those immense Globes of Fire, which enlighten our Night at so great a Distance, have each of them in particular a peculiar Appointment, which answers in God's Purpose the Magnificence of their Appearance. Doubtless, the Reason and Praise of these wonderful Works, about which the Creator had once employed himself, will greatly deserve, that we ourselves should be employed about them in that Life, after which we all of us so ardently aspire. But who shall presume to explain what the Almighty hath thought fit to conceal? Who shall dare to anticipate what he has reserved for another Octoconomy? The small

The Beauty and
Usefulness of
the Stars.

Glimpse which a few Genius's, more attentive than others, are by him permitted to have of those Objects, being perfectly unintelligible, and, as it were, unknown to the rest of Mankind; it is not in the particular Destination of each individual Star, nor in the general Harmony of these Spheres, that we are to look for the Means of instructing Man, or for the Way of regulating his Duties, and the Affections of his Heart. The prevailing Motives, which inspire him with Love, and incite him to Praise, must be drawn from what he sees, from what concerns him, and from what is evidently subservient to him. Now, what the Almighty has been pleased to reveal to him of the Order of the Heavens and the Stars, extends no farther than the Aspect under which he shows them to him, and the Use he allows him to make of them. But yet the little he vouchsafes to communicate to Man is full enough for him, and Matter sufficient for the most profound Admiration. God has so fitly placed the Habitation of Man, with regard to these immense Globes, that from that Situation there results an Order which he alone enjoys, a Beauty which enchant's his Eyes, and a Regularity which makes up the Happiness of his Life.

These innumerable Fires first become, through this wonderful Disposition, with regard to him, so many thousand

thousand sparkling Lustres hung up in the magnificent Ceiling that covers his Abode. He sees them shine and glitter on every Side, and the dark Azure, that serves them as a Ground, still heightens their Brightness and Splendor. But their Influences are gentle; their Rays are dispersed through Spaces so vast and immense, that they are entirely blunt and destitute of Heat by the Time they arrive at Man's Abode. Thus by the Creator's Providence he enjoys the Sight of a Maltitude of fiery Globes, without any Danger of their destroying the Coolness of the Night, or the Quiet of his Repose.

But it is not solely to adorn his Palace with costly Gildings, and a delightful Variety, that God every Day makes this magnificent Arch, with all its Decorations, turn around him. Man reaps, besides, many considerable Benefits from it. Among the Stars, which he can easily distinguish, he knows some that are always over his

The Stars that are near the Pole. Head, and constantly retain the same Place in the Firmament, without ever deviating from it. He sees others that de-

scribe very large Circles, and rise gradually above his Horizon, and then disappear, setting beneath the Extremities of the Earth, which terminate his Sight. The first guides him in his Travels both by Land and Sea, by shewing him in the Dark one Side of the Heaven, the Aspect of which remains constantly the same, and is sufficient to prevent his going out of his Way. But, as the Clouds, and the Thickness of the Air, may sometimes deprive Man of the Sight of those Stars that were given him as his Guides; God has put such an intimate Relation between that Part of the Heaven, and the Iron which has been touched with the

The Sea Com- pacts. Loadstone, that whenever that Iron is placed in Equilibrio, it incessantly turns one of its Ends, and that always the

same, towards the Pole. By this Means the Traveller is informed of the Place where those Guides, then not visible, remain, and his Way is always direct and regular, notwithstanding the accidental Disorders of the Atmosphere.

The other Stars. The other Stars vary their Aspect; and though they always keep their Situation.

tion among themselves, they nevertheless, with regard to us, daily change the Order of their Rising and Setting. These very Variations, by their Regularity, fix the Order of our Works, and by a few settled Points determine the Return and Conclusion of Seasons. Heat and Cold alone would have been too uncertain, and subject to too many fatal Revolutions, had they been made the Rule of Seed-time, and the Culture of Lands, or to distinguish what Times were proper for Navigation. Man finds all necessary Instructions on these Accounts, when he sees the Sun pass under a Series of different Stars, and yearly make the same Way in an uniform Manner. Thus it is that he knows the Course of that most beautiful Star. He assigns a Name to every one of the Houses by which it passes in its Way. He knows the exact Duration of its Stay in each House. He likewise is acquainted with the Abodes of the Moon and Planets, with the Limits of their Courses, and with the whole Oeconomy of the Months and the Year. He represents them in a small Compas with Machines, whose Revolutions are exact and regular. He, from one End of the Heaven to the other, observes several Points, Lines, Figures, and certain Marks that guide him in his Operations, and in the exact Division he is obliged to make of the Surface of the Land and Water. Thus is he acquainted with the whole Firmament; he delineates the Map of it, and very properly may be said to make a Voyage thither. But all these Objects, which he so usefully there distinguishes, dwindle and disappear at the Approach of the Sun; and if he distinctly determines which Stars are successively eclipsed by its Rays, it is from the Knowledge he has of their Remoteness, or Distance from those which Night discovers to him. It is then Night which, together with a new Scene, gives Man the surest Methods of ruling the Works and Order of Mankind.

Night is not confined to the Brightness of the Stars. It has other Fires that still enlighten Darkness much better, and form therein Pictures of a quite new Character. The Moon, above all, draws out of Obscurity the Objects that are nearest to us, and colours them in such a Manner, as agreeably changes their whole Appearance.

The

The Moon itself is then the most beautiful Object in Nature. It pleases the Eyes by the Softness of its Splendor, and varies the Scene in daily changing its own Figure. It every Day puts the Place of its Rising back from the *East* to the *West*. Sometimes it puts on an Ash-coloured Garment, almost intirely bordered with a plain gold Rim. Sometimes it dresses in Purple; and comes above the Horizon with a Shape much larger than ordinary. It lessens afterwards, and whitens as it ascends. It becomes brighter and more serviceable, as Day-light leaves us; and both when it but partly shews itself, and when it appears at full, every where gives new Ornaments to Nature, by suddenly breaking out, and successively sinking again among the Clouds; sometimes, by casting its Beams through a Thicket of leafy Branches; sometimes it decking itself with a Border of many Colours it borrows from the Clouds; or in attracting the Eyes of all the World; when the Earth, being placed between the Sun and the Moon, casts its Shadow upon the latter, and seems by Degrees to gain upon it, or totally to overspread it with Darkness.

Sometimes the Planet *Mercury*, but oftener *Venus*, appears, with regard to us, to discharge the Functions of the absent Moon; so bright is their Splendour, either at the Beginning of Night, or at the Break of Day. All these Lights, as well that which rules the Night, as the others which attend it, are most delightfully multiplied by Reflection in the perfect Mirror of Fountains and Rivers.

But that Night, which is at all Times a Summer greeable, is infinitely more so when the sultry Heats of Summer render the Day troublesome. It then makes Men relish all the Comforts that can make him Amends: It joins together with long Twilights, the Perfume of Gardens and Meadows, and the gentle Coolness of the Air. It offends his Eyes, much less than it amuses them, with a thousand little Fires that break through the Vapours of the Earth, with Lightnings that slightly flame the Edges of the Clouds, or with the Beams of the Boreal-fire, with which it often adorns the Northern Part of the Hemisphere, and sometimes

sometimes are observed to move from one End of the Horizon to the other.

Sometimes the Earth, like the Firmament, seems strewed with Stars. The Female Glow-worms, that kept under Ground during the Day, then come out to enjoy the Air; and then the Fields sparkle with new Fires. They are destitute of Wings to help them to look out for Company; but they are more sparkling than Diamonds; and their natural Brightness causes them to be seen in the Dark by the * Males, who have received Wings to come to them, but have not, like them, the Prerogative of Beauty.

Here, my dear Chevalier, methinks I hear you murmur; very likely you reproach me with leaving the Heavens, again to crawl upon Earth, whither the Brightness of those Insects had recalled me: But we have actually done with, and shall no longer swell upon them. Let us return to our Celestial Fires, and especially to the magnificent Light, whose Splendor is so much superior to that of others. The surprising Variety of the Aspects of that Planet, while the others seem to be constantly the same, raises a thousand Doubts in the Spectator's Mind, and gives Birth to many particular Reflections.

* The Chevalier *Vallière*, in his Work intitled, *Saggio d'Istoria Naturale*, Vol. III. Edit. fol. Pag. 429. tells us that one of his Friends having in his Hand a Glow-worm without Wings, another that had Wings, but was not reluctant, came into his Hand to meet the first, which was the Female. There are several Sorts of Glow-worms, and shining Beetles; especially in *America*: One in particular that wears a Sort of Lantern upon his Head.

THE M O O N.

DIALOGUE III.

A Very few Days ago, the Moon appeared under the Form of a Crescent, a little before the Dawn of Day. Now I see it under the same Form at the Approach of Night, with this Difference only, that, in the Morning, its Extremities or Horns looked towards the *West*, whereas the Horns of yonder Half-moon are extended and point towards the *East*. Three Days now are passed since the Moon has not shewed itself, either at the Approach of the Sun, or after its Setting: What then was become of it? Whither did it retire? What was it that screened its Light from us? Who has extinguished it? What Agent in Nature has the Charge of re-kindling that Lamp, and of returning it to us in so regular a Manner? Why will this luminous Crescent, in four or five Days Time, so far widen as to shew us the Quarter-part of a Sphere? How shall this Light, by its successive Increase, in something less than a Fortnight, come to shew me a Circle of Light somewhat defective on the left Side, and at length a complete and regular Disk or round Figure, perfectly luminous? When the Light begins to appear on the Body of the Moon, it gets up on the *Western*, then gradually spreads towards the opposite Side, and insensibly gains upon the whole Surface. Is it a Fire constantly increasing? But why does that Light, imme-

immediately after the Full-moon, begin to leave that very Side on which it made its first Appearance; it shrinks towards the Western Edge of the Moon, and by-and-by will be no more than a narrow Rim. That Rim afterwards dwindles to a small Thread without Breadth, and at last vanishes entirely. What can be the Cause of so inconstant a Light?

The Cause of so many Phases excites my Curiosity; but I find so constant a Regularity therein, that I should still be much better pleased to know the Purpose of such a Work, or the Usefulness of this Oeconomy. I think I can guess at the Aim and Cause of it; nay, methinks I even perceive them both very distinctly by making use of those Phænomena, which are certain, in order afterwards to obtain the Knowledge of what is not sensible to my Eyes.

In all the Eclipses of the Sun, which I have had an Opportunity of seeing, I remarked, that they always happen between the last Crescent of one periodical Course of the Moon, and the first Phasis of the New; that is, between the Time when the Moon is nearest to the Sun, and that when it begins to go off from it. All the Spectators, whom the sudden failing of the Light then drew together, saw in an uniform Manner, and shewed me either in still Water, or through a darkened Glass, a round and perfectly opaque Body, which insensibly slid before the Disk of the Sun, and either partly, or almost wholly, intercepted its Light. This dark Body could be no other than that of the Moon, which on the foregoing Days had been observed more and more to advance towards the Sun, and is found in one or two Days after to recede from it. The Moon, after having barred the Passage of that Portion of the solar Rays, which directly tended towards our Globe, appeared of the most horrid and deepest Black; from which I understand that it shines only as it is lighted. This Side, which is turned towards us, being not able to receive any Light from the Sun, had consequently none to give us. The Moon therefore is but a massy opaque Globe, whose Brightness is only the Result of a borrowed Light; it beats back towards us, or reflects the Rays that fall on its Surface, and cannot pass through it. This first Truth once known, all the rest are unveiled, and by this Help it becomes an easy Matter to see the Order of its Vicissitudes, and the Reason of its Phases.

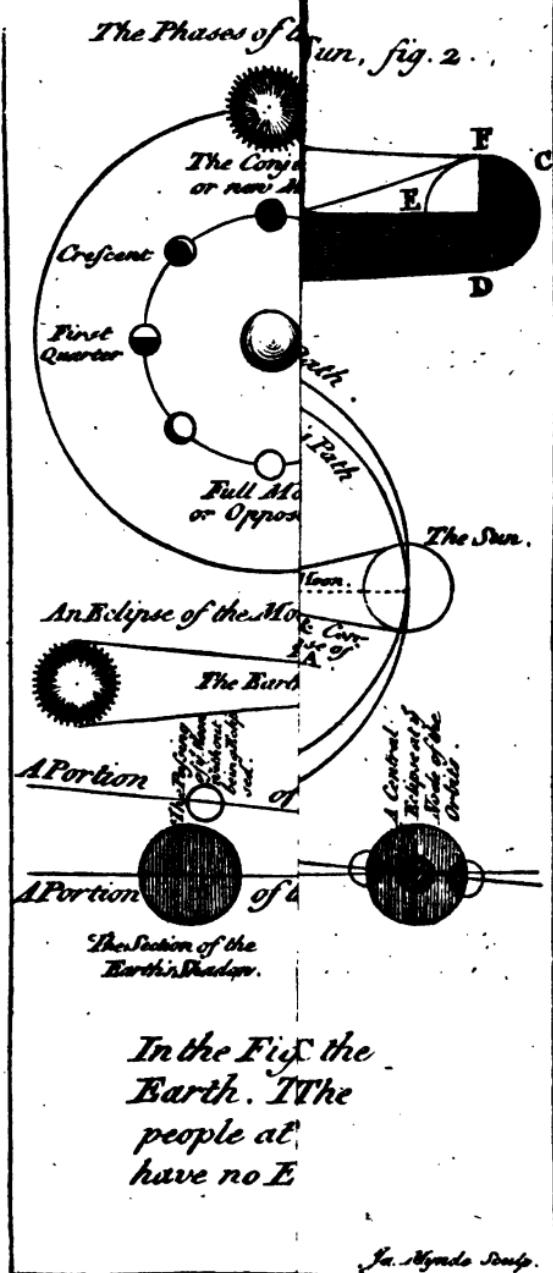
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At present let us not consider, whether The Motion of the Earth, by turning on its own Axis the Moon, before the celestial Bodies, shews to them as if they were moving round us, or whether the Heaven really turning, carries them along with itself from East to West. Let us even suppose that this daily Revolution of the Heavens is real, and for the present stick to what our Eyes seem to testify on that Head. The Moon, which makes a Part of the whole Mass of the Heavens, and is fixed to it, must of course be carried away from East to West. We shall see it rise, ascend, go down, and at last retire into that Half of the Heaven which the Horizon hides from us. But from the Manner in which it approaches to, and afterwards goes from the Sun, retiring always towards the East, we are convinced that it has a Motion peculiar to itself, whereby it advances in a Way contrary to that of the Heavens. While a Ship is moving from East to West with the Stream of the River, the Waterman, who is borne away by the Ship, does nevertheless freely walk from the Prow to the Stern, and from West to East. A Fly, placed on the Wheel that lifts a Weight, is carried downwards from above by the Motion of the Wheel; but she can by her own Motion gradually advance the contrary Way upwards from below.

Every Thing confirms us in the Notion, that the Moon has a peculiar Motion of its own, by which it turns round the Earth from West to East. After it has been between us and the Sun, and then passed from under that Star, it continues to retire still towards the East, and daily to change the Point of its Rising. In a Fortnight's Time it will have reached the most Eastern Part of the Horizon, when the Sun shall be observed to set; it is then in Opposition to that Star. In the Evening after the Sun is retired, it ascends our Horizon, and sets in the Morning very near the Time of Sun-rising. If then it proceeds in making the Circle it has begun round the Earth, Half of which is already finished, it visibly goes from its Point of Opposition to the Sun. By little and little it appears less remote from it, and consequently is seen later than when it was in Opposition; and at last draws so near that Star, that it will not be visible till a little before the Rising of the Sun.

If





If the perpetual Vicissitudes and progressive Retardations of the Moon, are an evident Consequence of its Motion, the Variety of its Phases is a no less sensible Consequence. No one is ignorant, that a Globe enlightened by the Sun, or by any other luminous Body, can receive the Light of that Body on only one of its Halves. The Light glances on the Extremities that terminate the enlightened Half. It continues its Way directly through the Air, without inclining towards the opposite Half, which of necessity must remain dark. When the Globe of the Moon is in Conjunction, that is between the Sun and us, its whole enlightened Half is towards the former, and the whole darkened Half towards us; thus is it invisible, though not annihilated; since no Object can be seen but by the Rays of Light that are reflected from it. But if the Moon has retired from under the Sun, and is withdrawn fifteen or twenty Degrees Eastwards, then it is no longer the whole darkened Half, which is turned towards us: A small Portion or Edge of the enlightened Half begins then to look towards us. We therefore see this luminous Edge on the right Side towards the Sun when but just set, or even before it sets, and the Extremities or Points of that Crescent will be to the Left, or looking Eastward. When afterwards it is got to the quarter Part of its Course round the Earth, it gradually turns towards us its enlightened Part, and shews us one Half of it. Now the enlightened Part of it is exactly one Half: The Half of that Half can then be no more than a quarter Part of the whole Globe; and that Quarter is, what we in Reality see. As the Moon retires from the Sun, and the Earth is nearly between them both, the Light covers a greater Space in that Part of the Moon which is towards us. When, at last, the Opposition shall become intire, and our Globe shall be directly, or almost directly, between the Sun and the Moon, the Light shall spread from one Border to the other, and the Half turned towards us shall be no other than the enlightened one. But the very next Day the enlightened Half shall begin to get a little behind the Moon with regard to us; the Half it turns towards us is not then exactly and intirely visible. The Light gradually leaves the Western Part, and in the same Proportion extends itself to the Half that looks from the Earth,

Earth, and the Extremities of the luminous Half shall successively pass over the whole anterior Disk on the Left; till the Moon being again about to pass between the Sun and the Earth, shews, at last, to her, no more than a small Border of that enlightened Half that is turned from our Eyes; and the Sun appearing in this Circumstance a little on the Left-hand Part of the Moon, with regard to the Spectator, the Crescent or Border of Light must needs stretch forth its Horns on the Right, or towards the West.

This Theory is self-evident; but should it require any new Proofs, they may be found in the Explication of the Particulars not yet examined.

We have very often seen the Moon in an Eclipse, and cannot but have remarked, that it never is so, but when it is in Opposition, that is, at the Full. This Phænomenon is a necessary Consequence of what we have just observed. The Moon may be in a perfect Opposition, and this will happen, if the Centre of the Moon, that of the Earth, and that of the Sun, are in, or nearly in the same Line. The Opacity of the Earth keeps the direct Rays of Light from reaching the Moon; she then is in the Shadow, and totally eclipsed. But if the Centre of the Earth be some Degrees distant from that Line which our Imagination may draw from the Sun to the Moon when in Opposition, the Shadow of the Earth shall slant only over a Part of the luminous Half of the Moon, or may wholly miss it.

For a like Reason, we conceive that the Time of Moon, when in Conjunction, may have its Eclipse of Centre in, or very near a Line that passes the Sun. through the Centre of the Earth on one Side, and through that of the Sun on the other.

In which Case it takes from the Earth the Light of the Sun, and either intirely eclipses, or partly hides it from the Earth. But the Moon, though in Opposition, may be distant from that Line one Half of its Diameter, or more, and then the Interposition of the lunar Globe causes no sort of Alteration. The very next Day she advances thirteen Degrees more towards the East than the Sun. She finishes her Revolution in twenty-seven Days, but does not meet the Sun at the same Point where she left him after the Conjunction. As the Sun itself advances towards the East in the Space of one Year, as much as the Moon does

does in one Month, she does not overtake and come under it again till after nine and twenty Days ; but in her perpetual Revolutions her Course is varied in such a Manner, that she very often passes under the Sun, without eclipsing it, and is frequently in Opposition with it, without being darkened by the Interposition of the terrestrial Globe.

You, perhaps, will ask me, whence is that faint Light which overspreads the whole Body of the Moon during the first and last Days of its having the Form of a Crescent ? This, as well as the Vicissitudes, Phases, and Eclipses, is no more than an Effect of the peculiar Motion of the Moon,

The faint Light of the whole Body of the Moon during the Crescent.

and of its particular Situation at that Time. The Earth reflects the Light of the Sun upon the Moon, just as the Moon herself reflects it upon the Earth. When the Moon is in Conjunction, the Earth is in Opposition with regard to her : It then properly is Full-earth with regard to the Moon, and the Beams, which the Earth casts on the Moon, are such, that the Moon may transmit it back to us by Reflexion. The whole Moon would then be visible at the Approach of the Conjunction, did not the Sun, which is then in her Neighbourhood, and which drowns the Light of the very Stars, wholly absorb that faint Light from the Earth reflected on the Globe of the Moon. This therefore cannot be seen, though there be no Interposition of any opaque Mass between it and our Eyes. When the Moon in Conjunction hides a Part of the Sun from us, what remains uncovered has yet a Brightness far superior to the dim Light, which the Full of the Earth may then cast on the Moon. When this causes a total Eclipse of the Sun, as it then robs a great Part of the Earth of all Manner of Light, it consequently can receive none from it ; much less can it send back any to us. But when the Moon is a little withdrawn from the Sun, and yet the Earth still almost in Opposition, the Light that passes from the enlightened Disk of the Earth to the obscure Surface of the Moon is there reflected, returns again to us though much weakened, and shews us the whole Body of the Moon, which not only is bordered with a golden Crescent, but also covered in every

other Part with a gentle Light, that distinguishes it from the Azure of the Heavens.

The peculiar Motion of the Moon from West to East, and the Variety of its Situations, are, as you see, sufficient to give us a very clear Idea of the ordinary Phænomena. It would be agreeable, after this, to be able to foretell the Instant when Eclipses would happen, and the Degree of Obscuration; to know the Difference of the Courses of the Moon from one Month to another, and the Rules of its Returns to the same Limits after a certain Number of Deviations. But let us not confuse the Order which we have proposed to ourselves; and reserving this geometrical Theory for another Place, let us see what is the Design of the Course and Phases of the Moon; it being a Matter of far greater Concern to us, than the most learned and exact Calculations.

If I use my Reason ever so little, I find in the Course of the Moon a Series of useful Designs, carried on for the Conveniency and Welfare of Man. That Body, as massive and dark as it is with regard to the Earth, has been placed in a Point, and an Orb so little distant from it, that it throws a greater Quantity of Light upon us, than all the Stars together, though they are as many Suns. Philosophers sometimes pity the common People, that know neither the Greatness of the Stars, nor the Smallness of the Moon. But such Philosophers as only shall consider the absolute Magnitude of those Bodies, would really be less clear-sighted than the common People themselves. For they perceive in the Moon, not indeed its real Bulk, the Knowledge of which is of little Concern to us, but a Light far superior in Brightness to all the Stars: And from the Relations the Creator has put between that Planet and us, it is evident that he had this good Effect in View. He has removed the Stars so very far from us, or keeps us so very far from them, that the Night we stand in need of cannot be impaired by their Brightness; and he has situated the Body of the Moon so near us, that it becomes a magnificent Glass, which returns to us in the Night great Part of the Light of the Sun which we had lost. It is true, the Motion of that Glass, thus successively placed all round the Earth, has been marked out by Lines, that heighten or lower in a seeming

seeming Irregularity: But these Wanderings and Deviations are limited, and by their Help the Moon is very seldom in an exact Opposition, or an exact Conjunction; that is, very seldom deprived of all Manner of Light by the Interposition of those Planets: Whereas, had the Course of the Moon been more uniform, we must every Year have had as many Eclipses of the Moon as Oppositions; that is, twelve, and likewise twelve Eclipses of the Sun at the Conjunctions. But there are Favours still more striking than these.

If a Man has a Mind to set out on a Journey before Day-light, or to prolong his Course till after Sun-set, the first Quarter offers its Assistance, and serves him as a Guide immediately after the Sun is retired. The last Quarter likewise does for his Sake precede by several Hours the Dawning of the Day. He may also defer his Journey to the Time of the full Moon, which affords him Days, as it were, four and twenty Hours long, by lighting him without Interruption. By this Help he can either avoid the burning Heats of the Summer, or at his Pleasure securely dispatch such Business as it may be his Interest not to trust to Day-light.

But would not a Night always clear have been more advantageous? God makes his Blessings of different Kind conspire to our Happiness, and the Variety of his Favours adds a new Value to their Excellency. The Moon is not only designed to moderate the Melancholy of the Night, by a Light that lengthens out, or replaces that of the Sun: It is a true Satellite, fixed first near Man's Palace, and charged with successively filling several Posts, and with giving him, in every one of these, some new Advice, or new Signal. The Sun was appointed to regulate the Order of rural Works by the Revolution of a Year: But the Moon, by making a like Revolution round us in twenty-nine Days, and regularly changing its Figure at the four Quarters of its Course, was ordained to rule civil Order, and the common Affairs of Mankind. It offers to all the Nations of the Earth a Watch-light, which takes every seven Days a Form entirely new, and presents them all with convenient Divisions, with Periods regular, short, and fit to determine the Beginning and End of minute periodical Affairs. Hence the *Hebrews*, *Greeks*, *Romans*, and all the

Ancients in general, used so assemble at the Time of the New Moon, to discharge the Duties of Piety and Gratitude; whatever might be of Concern to them, during the new Month, was proclaimed to them on that Day. They met again at the Full Moon, and the two Quarters were other Terms very easy to be pointed out. Nay, even to this Day, the *Turks*, the *Arabians*, the *Moors*, several *Americans*, and many other Nations, refer the whole Order and Oeconomy of their Calendar to the Renewals and other Phases of the Moon. Our being less attentive to it than they, does not prevent its being still as serviceable to us. The exact and convenient Calculations, which many learned Astronomers furnish us with, free us from all Manner of Care and Inspection that Way: But their Calendars and Ephemerides, that direct all our Affairs, are themselves governed by Observations of the Course of the Moon. They are before-hand adapted, proportioned, and reduced to the Advices, which this watchful Satellite will never fail to give us, till he, who for our Sake ordered its Station, shall think fit to change its Functions, together with the State of Man, in whose Service he had originally fixed it.

THE
C R E P U S C L E,
AND
A Z U R E of the H E A V E N S.

D I A L O G U E IV.

A Faint Light begins to whiten our Horizon, and we already see Day, long before the Sun, that pushes the Light towards us, is arrived at the Border of that Half of the Heaven which stands open before us. This Order of Nature has something surprizing to us; for we see the Light no otherwise than by the Rays that reach our Eyes. Now the Sun, being as yet in that Part of the Heaven which is hidden from us, and behind the other Half of the Earth, cannot, it seems, send any of its Rays directly to us. Doubtless it may make several of them glance upon the Extremities of the Lands that terminate our Sight: But these Rays proceed farther into the Heavens. If in those Spaces which they go through, they meet with any massy Body like that of the Moon, or any other Planet, they shall be reflected as in a Glass, and a Part of these Rays shall be sent back to us; but for Want of a Surface, or of a dense Body capable of reflecting them, they will pass on, and be all of them lost with regard to us. Is there in Nature any particular Body designed to do us that Service? If so, sure the Artifice and Mechanism of it will be the more admirable, because it serves us

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without being perceived, and the Usefulness of it be the more worthy our Gratitude, because this Caution was taken for our Sake alone.

See *Poëball on the Weight of the Air.*

Here you may recall, Sir, what we formerly have remarked of the Atmosphere, or that Mass of rarefied Water, and gross Air, wherewith God has enveloped the whole Earth. Nor are you ignorant, that the Column of Air, which keeps *Mercury* up to the Height of 27 Inches at the Foot of a Mountain, suffers it to lower till it is but 25, 24, and 23 Inches, or even less, as we draw nearer the Top of that Mountain; by which it appears, that the Pressure lessens in Proportion as that Column shortens; and by judging of the Relation between 27 Inches and three Quarters of a League, (by which Quantity the Height of the Atmosphere is diminished at the Top of our highest Mountains) it has been found by the plainest Calculations, that the Height of the Atmosphere may be about twenty Leagues. They conjecture, however, after many Experiments, that this Body may be incomparably higher and more extensive than it is commonly said to be; and have besides unquestionable Proofs, that it varies according to the several Degrees of Heat, Cold, Wind, Agitation or Repose, that are felt sensibly in it. It was in the vast Reservoir of rarefied Waters, of compressive Air, of attenuated Oil, of volatile Salts, and of other Elements wisely mixed together, that we formerly found the Origin of the perpetual Course of Fountains, the Principle of the Nutrition of Animals and Plants, the Source of Smells and Tastes, and many other Things of no less Importance. All these different Bodies, which are tossed about in the Atmosphere, are now no longer the Subject of our Speculations. The mechanical Frame itself of the Air must be our Study, if we have a Mind to understand, with any Exactness, not only the Birth and Progress of the Twilight, but even the wonderful Order of all Nature.

The Atmosphere is framed and disposed over our Heads in such a Manner, that notwithstanding its extensive Mass, it suffers us to see the Stars that shine at an immense Distance from it; and, notwithstanding its Transparency, bends

bends and gathers for us an infinite Multitude of Rays, which we should be deprived of without it.

Any Ray or Portion of Light, that falls directly and perpendicularly on the Atmosphere, enters it without any Obstacle, and through it descends on the Earth in the same Line. Of the Rays that fall upon it with greater or lesser Obliquity, some are admitted into, and some are repelled from it. When the Sun is as yet more than eighteen Degrees distant from the Line which our Horizon describes in the Heaven, then all the Rays offer themselves so obliquely to the Atmosphere, that instead of entering it they slant aside, and are lost in the immense Extent of the Heavens; like a Piece of Slate or Tile which a Child flings sloping on a River, and which falling very obliquely on the Surface of the Water, does but skim or graze upon it, bounds and rises again, and then repeats the same Thing more faintly, yielding at the same Time both to the oblique Impression or Impulse it has received, and to the Weight that forces it downwards.

But when the Sun comes to the eighteenth Degree from the Limits of the Horizon, this is very near the Point where the Atmosphere begins to admit the Rays that strike it: I say, very near; because that Point often varies. The Atmosphere rises or sinks according as it is dilated or depressed. When rarified by Heat, it is higher. Then the Sun, even before it reaches the eighteenth Degree from us, may meet it under that Degree of Obliquity, where transparent Bodies have been appointed to admit the Light. On the contrary, when Cold has depressed the Mass, as it is then flattened and lower, the Sun, when at eighteen Degrees Distance from our Horizon, is still below the necessary Degree of Obliquity, and its Rays still glance on the Atmosphere, instead of being admitted into it.

In vain should we here examine into the Reason why a Ray is not admitted into a transparent Surface, unless it makes an Angle of a certain Measure with it. It is enough for us to see the Matter of Fact, together with the Advantages resulting from that Oeconomy. On this Particular, as well as any other, we may affirm, that Nature has not, by adjusting itself, added Beauty to the Almighty's Work; but rather, that from God's immediate Intention of procuring that Beauty, Order sprung with the whole Frame of Nature. C 4 When

When the Rays offer themselves under the Degree appointed to enter into the Atmosphere, they not only are admitted into it, but are also bent and refracted there. In the first Place, they are bent and lowered more than they would have been in following the Direction in which they entered. It is an invariable Law of Nature, that when a Ray of Light passes obliquely from a transparent Body or Medium into a thicker, as from Air into Water, it does not follow the same oblique Line in its Way through it, but bends and becomes somewhat more convergent. We shall examine the Rules of this Convergency in its proper Place; and at present confine ourselves to the Knowledge of its Use and Effects.

All the oblique Rays that pass from the Heaven, and from the lighter into the thicker Part of the Atmosphere, do not follow their first Direction, but are bent there, which bending brings them out of their first Direction. This begins to brighten our Heaven long before the Arrival of the Sun.

But in order to regulate the Oeconomy of The Reflexion these Twilights, it is not enough that the of the Light. Atmosphere bends and drives towards us

a vast Number of Rays, that would not have reached thither, following the Course of their first Direction; it must, besides, continually reflect the greater Part of these Rays; for, in Reality, they are not all pushed towards us. The most numerous go through, and strike the very Bottom of the gross Air which surrounds us, whence they are brought again, or reflected on all the Objects about us. This Operation, which by the Bending or Refraction of the Rays causes the Dawn of Day, produces also its Continuation and principal Beauty, even when the Sun is in its greatest Degree of Elevation, and casts on us all its Heat. The Earth, that receives these Rays, beats them back on all Sides; they ascend again into the Atmosphere, which again returns us the greater Part of them. Thus does it make them doubly useful, preserving to us that Heat which is the Soul of Nature, and that Splendor which is the Beauty of it.

The Atmosphere is the Cause of Heat. It evidently increases the Heat, since it gathers together a numberless Quantity of Rays, the greater or lesser Union of which is the Measure of Heat and Cold. Thus the

the Atmosphere becomes to Man a Mantle of the finest Texture, which, without making him sensible of any Manner of Weight, keeps in that vivifying Heat, which, were it not constantly confined, would soon be lost.

The Atmosphere does at the same Time cause and maintain around us that brisk It is the Cause and universal Light which lays our whole of Splendor. Habitation before our Eyes, and which, though it be a necessary Consequence of the Irradiation of the Sun on the Atmosphere, yet is the Work of the latter, rather than the Production of the Sun it self. You certainly will look on this as a Paradox. How ! you will say : If it is properly the Atmosphere that produces the Day, by collecting for us the Light which the Sun casts upon it ; let us for a Moment suppose the Atmosphere to be destroyed ; in this Case we may see the Sun without having Day ; it then will no longer be the Father of Light ?

I admit your Supposition. Let the Atmosphere be no more, and the Earth lie naked under the Sun.

At first, the Rising of that Star has not been preceded by any Twilight : It has not been ushered in by the Aurora, there being nothing to reflect towards us the least of its oblique Rays. The most intense Darkness covers us to the very Moment of its Rising. It suddenly breaks out from under the Horizon, shews itself such as it will appear towards the Middle of its Course, and will not in the least change its Appearance to the Instant of its Setting, which shall be as obscure, with regard to us, as the Middle of the darkest Night. The Sun, it is true, strikes our Eyes with a lively Brightness ; but supposing the Atmosphere annihilated, it is like a clear Fire which we see during the Night in the Midst of a spacious Field. It is Day-light, if you will ; for we see the Sun and the adjacent Objects round us : But the Rays, that fall on such Lands as are a little remote, are for ever lost in the vast Expanse of the Heavens. These Lands are not perceived, and the Night still continues, notwithstanding the Fire of this bright and brilliant Star. For instead of the white Tint or Colour which characterizes the Day, and unveils all Nature by brightening the Azure of the Heavens, and colouring all the Horizon ; we see nothing but a black Deep, an Abyss of Darkness, wherein the Rays

of the Sun meet with nothing that can reflect them to us. It is true, the Number of the Objects shall seem to be augmented in the Heaven, and the Stars seen as well as the Sun : But this is a new Demonstration, that there is no Day to be had without the Atmosphere ; since it is that alone, which, by multiplying the Reflexions, strengthens the Light of the Sun so far as to make it drown that of the Stars. The Sun then mounts, if you will, over our Heads ; but for want of an Atmosphere it would always be Night, and the Difference between that Night and ours would consist in this, that the luminous Bodies, which light it now, are grounded on a pleasing and delightful Azure ; whereas, in the other Case, they would seem fastened on a dismal mourning Carpet.

You, perhaps, cannot conceive how the Destruction of the Atmosphere carries with it the Loss of that fine Azure, that adorns the Heaven, and delights the Earth : But you will easily frame a just Notion of it to yourself, if you do but recall what a prodigious Quantity of rarefied Water is raised on high, and buoyed up from the highest Part of the Atmosphere down to us. There never is a greater Quantity of it collected there, than in the finest Summer Days, when there are no Clouds, or Vapours to be seen. Thus, though these Waters, higher than the Region of the Clouds, escape our Senses, your own Reason points out their Existence to you, and the Operations of Nature convince you of it in Concert with the Legislator of the *Hebrews*, who had been informed of that Division by the Author of Nature himself. It is among these Gatherings of Light and rarefied Waters always suspended over our Heads, that all the Rays of Light reflected from the Surface of the Land meet. The Atmosphere again sends them back to us from all Parts. This vast Mass of rarefied Waters which surround us, being a simple, and uniform Body in its whole Extent, the Colour of it is always simple, and constantly the same. We shall afterwards see, in its proper Place, that those Rays of all Kinds that are sent back by the Atmosphere, form the white Colour by their Union. We shall see likewise, that the immense Spaces reaching from us to the Stars, not reflecting towards us any Manner of Light, must needs appear black to our Eyes. The blueish Colour is what God has

has given to Water, whether condensed or rarefied. The Atmosphere therefore must be of an azure Colour; and this Azure is sometimes lighter in Proportion to the Quantity of Rays, which enter the Atmosphere and are there reflected; sometimes deeper, when the Absence of the Twilight heightens the blue of the Atmosphere, by Means of that black, which follows it immediately.

How! those azure arched Skies which we confounded with the starry Heaven, are they then nothing more than a little Air and Water? and what we took for the Heaven, only a Cover wrapt close round the Earth? It is indeed nothing else; and this again is a new Wonder, that requires something more than bare Admiration. It is a complete Demonstration of our being the Objects of our Creator's tenderest Affection. A few small Bubbles of Air and Water are indeed of themselves Things very insignificant: But that Hand, which had with so much Art and Caution placed them over our Heads, has done it merely that his Sun and Stars might not be rendered useless to us. He embellishes and enriches whatever he pleases, and these Drops of Water and Air become in his Hands an inexhaustible Source of Glory and Happiness. He draws from them those Twilights which so usefully prepare our Eyes for the receiving of a stronger Light. He fetches out of them the Brightness of the Aurora. From them he produces that Splendor of the Day, which the Sun of itself could never procure us. He makes them contribute to the Preservation and Increase of that Heat which nourishes every Thing breathing. Of them he makes a bright Arch, that enchant's the Sight of Man on all Sides, and becomes the Cieling of his Habitation. God might have made that Arch darker, or even black: But the black is a sad and dismal Colour, that would have thrown all Nature, perhaps, into the deepest Melancholy. The red and white were as little proper for it, since their excessive Brightness would have offended every Eye. The yellow is reserved for the Aurora: Besides, a whole Arch of that Colour would not have been sufficiently distinguished from the Stars that were to be seen through it. The green, as it is very sympathetic and pleasing to our Eyes, would indeed, have produced all the necessary Embellishments: But it is with that lovely Colour that God has adorned

our Abode. It is the Carpet he has spread under our Feet. The blue, without any Sadness or Hardness in it, has the additional Merit of approaching near unto and heightening the Beauty of the Stars.

The Workmanship of that Arch, though it limits our Sight by its Thickness, is transparent enough to let us extend our Sight as far as the Stars. And though it is so very near us, yet seems to make but one Body with them, though they are at an inconceivable Distance from it. This is as it were the Bond that unites all Things far separated by Nature: Let me then ask a sincere thinking Believer, why God has spread this Atmosphere round us? A false Philosopher will take it for the Sediment of some Vortex, and think he has hit it right: But Piety, more penetrating, sees there what strikes the Eyes of all: I mean, an evident and palpable Intention to establish Man in the Possession of Nature, and to present him with an Oeconomy and World designed for him alone, since he is the only Spectator of it.

I cannot take my Eyes off this luminous Arch, which affects me less by its Magnificence than by the Blessings it procures me, and by that innumerable Series of Precautions that have been taken for my Sake. But while I follow the Order of those Thoughts which the first Dawnings of the Day might raise, I perceive the Beginning of the Aurora. Let us not give ourselves over to the Pleasure of examining this new Decoration, before we have taken Notice of the chief Benefit of the Twilight. The Design of this was, no doubt, to prolong the Day; that Man might also prolong his Work and Travels, and at the same Time not to bring Day-light upon him, before his Eyes were prepared for it; nor the Dark, before he was forewarned of it.

But the Crepuscles vary from one End of the Year to the other, and they are far greater towards the Poles, than in the Torrid Zone. Is there then the same Artifice and Utility in the Variations of the Crepuscles, as in the Cause that produces it?

The Inhabitants of the Torrid Zone see the Sun ascending perpendicularly their Horizon, and going down in the same Direction into the upper Hemisphere: Whence it happens, that the Sun comes very soon to be eighteen Degrees

Degrees below the Horizon, and leaves them in the darkest Night. On the contrary, as it casts its Rays obliquely towards the Poles, and goes not very far below the Horizon of those who are near them; it thence happens, that their Nights, though very long, are always accompanied with Crepuscles, and are in a Manner luminous. The deep Gloom of the Night again brings with it a comfortable Coolness to the Inhabitants of the Torrid Zone, whose Spirits the excessive Heat of the Day has intirely exhausted. The Remains of an almost continual Light are extremely precious to the People neighbouring on the Poles, and free them from a Darkness that would render their Life unhappy. It is a Blessing to the former, to have scarce any Twilight at all, and it is no less agreeable to the latter, that they have an Aurora which is scarce ever interrupted.

As for us, who are pretty equally distant from the Inhabitants of the Torrid and Frigid Zones, we, by Experience, have Crepuscles as diminish in Proportion to the shortening of the Days, and increase nearly in Proportion to their lengthening. At first Sight this Oeconomy seems grievous to us, and one might be apt to think, that as we can do without Light very well, when the Nights are extremely short; we on the contrary should be very glad of a fine Twilight, when they are very long. But nothing would be worse managed than the Government of the World, were it abandoned to the Conduct and Reason of Man; and nothing can be better contrived than what God has established, even when it seems contrary to our Nations. Of this you may judge by the Oeconomy of the Crepuscles, of which we might be inclined to complain.

Nights become longer, and the Darkness deeper, after a Man has gathered in all his Harvests. Then the Earth, no less than he that tills it, wants to take its Rest. Winter comes to refresh them both, and to make them recover, during the Time of Inaction, the Strength necessary, ere long, to begin Labour a-new. Night may lengthen without any dangerous Consequence, when the Husbandman is unemployed, as is Nature itself. What would Crepuscles be good for, while Man is at Rest?

But Night will gradually gather up its Veil, and yield Man new Degrees of Light, as the Necessity of working

shall bring on the Necessity of being lighted. During the Summer, Night, for the Sake of Man's Works, continues to lengthen out the Crepuscle for his Use, even when it has begun to lengthen itself out by a sensible Diminution of the Days. When the great Heat shall solicit Man to cut down the Grass or the Corn it has brought to perfect Maturity, Night then, lest it should be destroyed by the Heat of a burning Sun, invites him to put off a great Part of his Toil to the Time when she comes to cool him. To gratify him, she becomes an almost perpetual Aurora. In the Summer Season, a faint Light, more or less considerable, constantly chears the Horizon towards the Evening between the West and the North, and between the North and the East towards Morning. Man sees distinctly what comes under his Sickle or Scythe, and the Mildness of the Air allows him to cut his Harvest down without Sweating. The Summer, which renders his Travels more easy and convenient to him, and facilitates the Fishing and Trade of the North, accommodates itself to all his Wants, and kindly lights all his nightly Operations, at the very Time when the Rest he takes, during the Heats of the Day, renders his Night-watches necessary.

Here, my dear Chevalier, I would fain ask you, among all the Methods one may follow in studying the Economy of Crepuscles, pray, which would you give the Preference to ? I, for certain, blame none of them ; but I may be allowed to try your Judgment. The Order of Crepuscles may be studied after the Method of the Philosopher, or after that of the Ploughman. The former calculates the Difference of the crepuscular Light from Day to Day, and his Work may be so exact as to procure him general Applause. The Husbandman is not so learned; but at those Hours, when he is at Leisure from his Work, he sometimes reflects upon the Heat that ripens his Harvest during the Day, and on that gentle Light which comes to assist him to cut it down at Night. He is pleased, to see the Coolness concurring with the Light to forward his Labour. He perceives God's Intention in this beautiful Economy, and renders him therefore Thanks and Praise. Both these argue and philosophise after their own Manner. But if the first has looked upon the Atmosphere, wherein the Crepuscle is produced, only as a dusky

Mist,

Mass of Matter, which Gravity has collected round the Planet; if he has neither discerned nor adored the Hand that rules and bestows this Light on Man, by lodging him beneath an Atmosphere; pray, which of our two Philosophers do you prefer? Which do you think argues best? You, no doubt, have a Value for Calculations and Exactness; but I am sure you will declare for the Philosophy of the Mind.

THE A U R O R A.

DIALOGUE V.

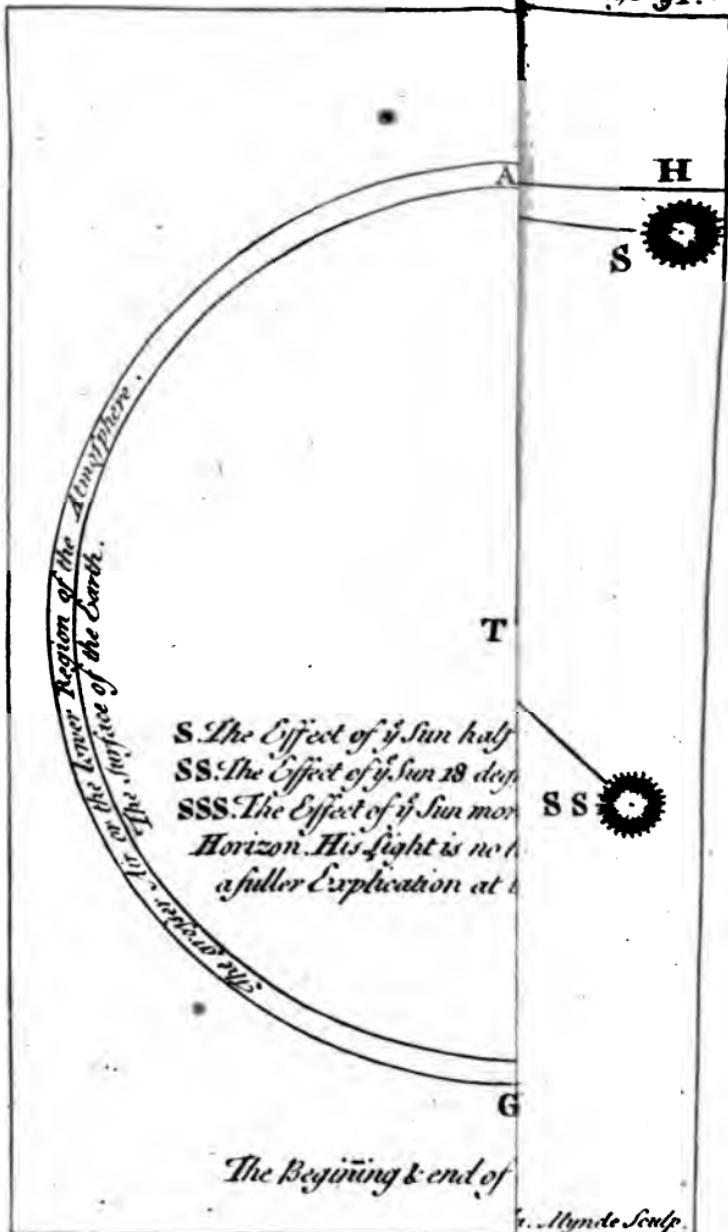
BOTH Heaven and Earth have their agreeable Variety. Every Moment brings with it something new. That Circle which cleared up and whitened the Azure of the Firmament towards the East, now widens and rises upwards. The Objects, which we were scarce able to perceive, begin now to be clearly distinguished: It is Day-light, and the Crepuscle is at last succeeded by the Aurora.

* Poets, who know no better Method of pleasing, than that of making lively Pictures of Things, have given us the pleasant Descriptions of the Aurora. They make her the Daughter of the Air, and stile her the Forerunner of the Day. In this Quality she is charged with the Custody of the Gates of the East, and it is she who, at the appointed Time, comes to open them with her rosy Fingers. She sends before her the Zephyrs to scatter gloomy Vapours, and to purify the thickened Air. Wherever she appears, she enlivens the Verdure, makes Flowers grow under her Steps, and with the News of the Day, spreads Beauty and Joy all over the Universe.

These

* Αύρανία φανή ποδοδάκιλος ήνε, Homer, Odyss.





The Beginning & end of

J. Mynde Sculp.

These poetical Fancies have something in them very agreeable; but the fabulous Strokes, with which Truth is blended therein, are nothing but a Paint, that disfigures it and impairs its Beauty. Let us then leave the poetical, and consider the natural Aurora. This, indeed, is so majestic and so bright, that it wants no borrowed Help, or, Decorations, to be infinitely pleasing.

The Aurora, with regard to us, is a Creation intirely new, and every whit as noble and free a Gift as the first Creation. It is wholly new, since the Aurora causes Heaven and Earth to rise out of that profound Darkness, which took from us the Sight and Use of them, as if they were no more. It may even be said, without derogating from the exactest Truth, that the Birth of Light is finer and more magnificent at present, than it was at the first Moment of its Creation. There were then no Spectators, nor any Objects to be enlightened. The Earth, it is true, was already made: God had formed the several Parts of Matter, he had with Oeconomy spread the various Strata or Layers, and prepared all the Organs thereof: But the Animals, the Plants, and all the Works, wherewith it was to be covered and adorned, were not as yet upon it. They appeared thereon but successively, and within the Compass of several Days, as God was pleased to regulate their Being, and assign them their respective Places. The Waters of the Atmosphere had not yet been raised on high, nor those of the Sea collected and confined within the lower Places wherein they now sojourn. These Waters covered the whole Earth: In short, it was as yet without either Order or Beauty. But now, when the Dawning of the Day scatters the Darkness, it opens to our Sight an Earth strewed with Blessings, and embellished, for our Sakes, with the most costly Attire. It unveils every Thing to our Eyes; It shews us the Mountains, with the spacious Woods with which they are crowned: It offers to our View the lesser Hills, with the Vines, that are like Tapestry upon them; the Fields, with the Crops that cover them; the Meadows, with the Rivers that water them: It draws the Curtain from over whole Cities and Towns: It brings out of Darkness the Domes and Pyramids of Temples, the magnificent Castles of the Great, and the Abodes of the People dispersed all over the Plain.

AN

All these Treasures were lost to us, so long as the Night made them of no Use. It seemed to rob us of them, or to annihilate them; and as we have no Title to the Day that restores them to us, the Return of the Aurora is of Course a Benefit conferred on us, not only as new and as magnificent, but likewise as little deserved, and as greatly bountiful, as the Creation itself.

God, it is true, creates no new Beings in the material World; and in that Sense he is, indeed, entered into his Rest. But as nothing began to exist but because he was pleased it should be; and as every Thing would cease to be and to act, should he cease to will their Duration, Motion, and periodical Return; * he acts as much at every Instant for the Preservation of the Universe, as he did at the first Moment of its Creation. He then began to will that it should, and he continues to will that it may subsist. Therefore each new Day is as great and special a Mark of the divine Favour as the first.

But Men will, perhaps, argue thus: Why must Recourse be had to the Will of God, when every Thing is to be accounted for by following the simple Order of Nature? It is weak Philosophy to look for Intentions, and to suppose any particular Gifts in the Return of the Aurora. It is nothing more than the Beginning of a new Revolution of our Vortex, and a mere and plain Consequence of the Laws of Motion; it is, indeed, an immediate Effect of the Motion, or of the Revolution of the World: But there may be some Danger in the Manner in which Naturalists speak of Motion to such as listen to them. They are apt to lead Youth into Mistakes, who make Motion or Nature an Idol, which they place in the Room of God, and to which they attribute every Thing, as to its necessary Cause. Whence it happens, that while they think themselves more knowing than the rest of Mankind, they are really ignorant both of God and his Works, and become Idolaters instead of reasonable Creatures. And indeed, what are Motion, and the Laws of Impulse? Motion is evidently nothing but the Body moved or displaced. The Strength of that Motion,

* My Father worketh hitherto, *Job v. 17.*

tion, and the Duration of it, are nothing but the constant Order and Oeconomy which God has prescribed to himself, and according to which he regularly continues to preserve and dispose of every Thing. The Laws of the Clashing of Bodies one with another, or those of Percussion, are the same with the Decrees by which God has regulated these Clashings. The Velocities of Motion are nothing but the Execution of his sovereign Will: In short, the moving Force, the Nature of which Philosophers are so much at a Loss how to determine, is in Reality nothing but the Action itself of God, differently applied or distributed with Oeconomy and Design. A Body moved continues its Motion in a direct Line, till it meets another Body: Not that, after having traversed the Space of one Foot, it has acquired any real Force to go through a second; but because that Continuity of Motion, and the Alterations that happen in the Clashing or Percussion, are Consequences of those Laws by which Nature is regulated; and this Order subsists, because God is faithful in the Execution of his Plan. But as he follows it with an intire Liberty, there is no Manner of Necessity that Night should be succeeded by the Aurora, or this be succeeded by the Sun, whose Arrival it foretells. I should then argue with as much Stupidity as Ingratitude, should I see nothing more in the Aurora, than the four and twentieth Part of daily Revolution, instead of adoring it in that free, efficacious, and persevering gracious Will, that restores us again from Nought and Darkness, in reviving the Light, and which, with the Day, renews the Service of all Creatures, for us.

To this Favour of the renewing of the World, the Aurora adds another not far inferior. It gives new Life to Man himself, in raising him from Sleep, which is the Image of Death. The Morning restores him to the Use of his Understanding, his Arms, Talents, of which Sleep had intirely robbed him. It warns him of the Time when he is to return to his Work. This indeed would not be the most agreeable of its Offices were Labour nothing but mere Pain and Trouble: But as it is the necessary Exercise of Virtue, it is likewise the Source of true Happiness. The Aurora comes on, without any Variation, or giving any Quarter, to declare the Hour of Labour. It lays Man under

under Constraint for his own Service: It strikes vigorously on his Eyes: It has already taken the Care to make all his Servants get up. He, whose Charge it is to wake the rest, has faithfully told them before-hand, their Master was ready to set out; and left Men should find them asleep at the Hour of his waking, the Cock has several Times repeated his Summons; in short, all moves according to Order. The rest of the Birds are in the Fields before Man. They fill the Air with a thousand pleasing Notes that reach his Ears, till he is intirely awaked. The Beast of Burden and Cattle wait only for his Orders, and make themselves ready to move on the first Signal. Man at last leaves his Bed and House, and all attend him. From all the Villages within my Sight, I see Husbandmen followed by their Horses; Travellers on Foot, in Coaches, or on Horseback; Shepherds at the Head of their Flocks, and Workmen loaded with their Tools. The Roads, Bridges, Ports, Markets, and all public Places, begin to swarm with People: All Mankind are in Action. The Aurora has declared the Hour of working: It is she that causes this universal Motion.

But when I see Man set out for his Work, with all the Animals that serve him, I am amazed to see some that chuse that very Moment to retire to their Abodes, and which go to Rest, or hide themselves, instead of enjoying the Charms of Day-light. I don't mean those melancholy Birds, who are scared by the Light; but I mean a great Number of Animals which are no Enemies to it. If I take my Eyes from the Plains, to observe what passes at the Entrance of the Woods, I see here Rabbits retiring; then Wolves or Foxes; in another Place Harts and Hinds, followed by their Fawns; in some other Place wild Boars, attended by a Herd of their Young. Sometimes a Deer or a Roe-buck; sometimes other Animals, that are either cruel or capricious, but all of them wild and untractable. What can thus force them to retire? Is it the Light? No, sure: That pleases them sufficiently: They enjoy it as long as they can: They hasten not to be deprived of it. It is evident from their slow and often interrupted March, that they re-enter Darkness much against their Inclinations: What then can thus drive them from

from the Plain, where they all find their Subfistance ? Is it the Sight of Men ? But these are very remote, and those who shew themselves are without Arms, or any other Cau-tion or Defence. One sings in getting ready his Plough : The other tries his Pipe, lying on the Grafs by his Dog, whom perhaps he has tied up : The Traveller pursues his Journey with the utmost Indifference : There is no Man-ner of ill Design, nor any Declaration of War : Yet all these Animals get into the Woods, as well in those Coun-tries where there are no Hunters, as in those in which they are most formidable and troublesome to them. Therefore, it is not Terror which calls them together into the Woods. Were they frightened, they would run precipitately : Their Retreat would be a real Flight. How can Man not perceive, in this Dispensation, the Work of that Providence which submits every Thing to him ? She has treated him as the absolute Master and Proprietor of the Place he inhabits. When he is pleased to go out to visit his Dominions, the wild Beasts that are to serve him, with-out shewing themselves, or being any Way troublesome or expensive to him, leave him the Place free ; and though it be more easy for them to find their Food in the Plain by Day than during the Night, the Aurora, by introducing Man there, warns all wild Beasts not to appear. They know the Hour and Signal, and respectively retire. An irresistible and powerful Hand, in spite of them, drives them into the Forests, and the Lord of the Earth sees now nothing that can any Way interrupt his Work, or restrain his Liberty.

The domestic Animals, and all those that live near the wild, behave with Discretion. They never go, without Commands, to annoy them in their Solitude : They even keep from them with a Kind of Prudence, and are sensible of the Danger of approaching them too near. They all know their Bounds, and keep within the Limits of their appointed respective Districts. From this noble Oeconomy, in which Man has not the least Hand, result a thousand Advantages to us, and us alone.

As the Aurora rises, we receive several
The Winds and other Benefits of a quite different Kind.
the Morning The Sun had, during the whole foregoing
Dew. Day, raised from the Surface of the Plains
and

and Waters, a vast Quantity of Bubbles of rarefied Water and Air, and draw them very far from the Earth. Those that were last raised, had immediately fallen again at the going down of the Sun, and the withdrawing of its Heat. They had gathered again in their falling, and formed the first Coolness of the Night, which is called Dew. But the other Bubbles, which in the long-continued Day had got through the grosser Air, and placed themselves in Equilibrio with the Upper-parts of it, in the superior Regions, had remained suspended therein during the Calm of the Night. At the Approach of the Sun, the first Efforts of its Heat beginning to affect the Air, grown cool and condensed, necessarily dilate it. One Quantity of Air, dilated by the Heat, pushes another, which is resisted by a third. This Emotion of the Air becomes a Wind, sometimes gentle, sometimes cool, and as piercing as the North-east Wind. The Atmosphere is more or less agitated by it. The rarefied Water is tossed by these Shocks, that make it condense or gather again. Such is the Zephyr which the Aurora employs to carry before her the Dew, which becomes the most delicate Nourishment of Plants. The Earth drinks it in: The Leaves of Trees, like so many open Hands, bow, in order to receive it, and the Flowers open on all Sides to partake of that Treasure. The coming of the Aurora is to these Productions a most precious Moment, which, by insinuating so light and fine a Distillation into their Pores, conveys therein at the same Time a thousand Particles of Oil, Salt, and Air, which the Action of the Sun afterwards distributes through the whole Body of the Plant.

* But let us not be so intirely taken up with the Good and Favours done to us, as to forget to bestow a Part of our Attention on the Delight that heightens them. I see the whole Circle of the Horizon gradually inflamed with the brightest red. The Clouds every where contract various and lively Colours. The Edges of the thickest amongst them become Fringes brighter than Silver: The thin Vapours that cross the East there become like Gold. The Green of the Plants, attenuated by the Drops of Dew which cover them, give them the Sweetness, and
all

* The Beauty of the Heaven at the Approach of the Sun.

all the Lustre of Pearls. But though Nature be extremely beautiful at that Moment; yet we are still more attentive to what it makes us expect, than affected by what it lays before our Eyes. The perpetual Increase of the Aurora makes us sensible that it forebodes something still more perfect. It is a gentle Medium, which, by gradually gathering Strength, facilitates the Passage from Darkness to broad Day-light. Each Moment adds something to the foregoing. We go from Light to Light. We long to see the Fulness of it. What is granted to us for the present yields no more than a Foretaste, and makes us long for what is the Source and Spring of it. The Hour is determined, when it shall appear in all its Glory. The happy Moment is near at Hand, but still expected.

THE
R I S I N G
OF THE
S U N.

DIALOGUE VI.

NATURE, at last, presents us with its most glorious Objects. The Sun rises. One single Ray escaped from behind the Top of the Mountains, which before intercepted the Sight of it from us, darts from one End of the Horizon to the other. New Tracts of Light follow, and give new Strength to the first. The Disk of the Sun disengages itself by Degrees: It now is seen intirely, and ascends the Heaven, with a majestic State, which attracts and fixes all Eyes upon it.

A few Moments before, I perceived an Its Unity. innumerable Multitude of Flambeaux on every Side: But the Light they all together yielded me, did not render the Earth visible to my Eyes. They were indeed of some Use to make me distinguish what was round me, at very small Distances: But even among all these Fires I remained still in the Dark.

Now

Now in the whole Immensity of the Heavens a single Flambeau strikes my Eyes, and it not only makes me Amends for the Loss of the other Lights, overwhelming them all by the Superiority of its own, but even over-spreads Nature with such Splendor and Glory, as changes the whole Face thereof.

What then can this Globe be, which alone causes a general Renewal at the very Instant of its Appearance? In vain do I cast my Eyes, and fix my Attention upon it: I can by no Means bear its Aspect, and its inmost Nature escapes all my Researches. Is it a Globe wholly composed of Fire? What are the Fire and Light which it casts from all Parts? Are the Light and the Fire but one and the same material Being? Or are they two distinct Things which go together, and one whereof continually pushes forward the other? How can that Globe operate so powerfully, and at so vast Distances? How comes it, during the six thousand successive Year, it has given Light and Heat to Nature, not to have lost the greatest Part of its Substance, by the constant Effluvia emitted from it? Has it then a Reservoir that repairs all its Losses? Is there a perpetual Circulation of Fire and Light, that incessantly replaces in the Sun what is uninterruptedly emitted from it? Or is the Action of the Sun no more than a powerful Pressure of its Fires on the Body of the Light, so that that Star communicates its Action to us, without undergoing the least Diminution or Loss? We shall, perhaps, hereafter, explore the most plausible Answers that can be made to these sublime Queries. Let us for the present confine ourselves within what is past all Dispute, and inform ourselves of what may be relied upon with Certainty, on the Measure, Distance, and Operations of that Globe. God at present hides from us nothing but what is useless or dangerous; and it would be acting contrary to our Interest, (to which God has proportioned the Knowledge he gives us of his Works) should we reject the Truths he reveals to us.

Geometrians have a Way equally plain and sure to measure inaccessible Bodies. Its Distance When they know the Measure of one Side and Size, and two Angles of a Triangle, they quickly determine the Quantity of the third Angle, and the

Length of the two other Sides. Or, when two Sides and one Angle are known, they immediately find out the other two Angles, and the unknown Side. By this Skill, about which I shall in another Place have an Opportunity of entertaining you, it is, that they daily inform us, what the exact Height of a Tower or Hill can be, without ascending it; what the Depth of a Well, without going down to the Bottom of it; and the Breadth of a River, without coming near the other Shore. In like Manner Astronomers know how to describe a Triangle, of which they know one Side exactly, which represents the Semi-diameter of the Earth. They, besides, know the exact Measure of the two Angles formed upon that Side, by two Lines that meet together in the Center of the Sun. Thus they know the exact Measure of the two Sides that represent the Distance of the Earth from the Sun. By these, or some other no less certain Operations, they judge of and determine the Magnitude of the Stars. It is true, the Observations of the Moderns have greatly swelled the Calculations of those that were before them; which is a Proof, not that this Science is frivolous, but that the Instruments therein made use of every Day acquire a new Degree of Perfection. However as a single Minute, or even a Part of it added or retrenched, immediately makes a Difference of several hundreds of thousands, or even millions of Leagues; let us take the grossest Calculations and Sums that can have no other Fault but their being inferior to the Reality of Things. Thus we shall run no Risk, but that of setting on the Works of God a Price inferior to their true Value, and avoid the Danger of admiring a Beauty that is not in them, or any Thing extraordinary, of the Existence of which we may may not be sufficiently assured.

There is now no Astronomer but knows by evident Proofs, and by the plainest Calculation, that the Sun is almost a Million of Times bigger than the Earth. Let us here be contented with asserting, that the Mass of the Sun is a hundred thousand Times bigger than that of our Sphere. Besides which, there is no Astronomer that does not judge the Sun to be distant from us above five thousand Times the Breadth of a Diameter of the Earth.

And as that Diameter * is above three thousand of our common Leagues long, taking only two thousand Fathoms for each League, if we multiply 5000 by 3000, we are sure that the Sun is above fifteen millions of Leagues distant from the Earth. We should be frightened at the Thought of what the most learned and most exact Astronomers, in their Calculations, add to these Measures. Mess. *Cassini* and *Newton* judge the Distance of the Earth from the Sun to be ten thousand Diameters of the Earth, which makes thirty, or even thirty-three millions of Leagues. If I confine myself to the Half of the Product of their Calculations, notwithstanding the Exactness and Regularity which no body can refuse to ascribe to these great Men; of course I shall not be suspected of any Intention here to augment the Marvellous.

To be made the more sensible, what a prodigious Space that Half still is, imagine to yourself a Horse, and a Cannon-ball, that start from the Earth in order to get to the Sun, and continue their Way with a steady Pace, without any Faintness or Interruption. Let us suppose the Horse to make his Journey of 25 Leagues a Day; and the Ball to go through the Space of an hundred Fathoms every Second. In multiplying 25 Leagues by 365 Days, the Horse would make 9125 Leagues in a Year. After having travelled at this Rate for 1550 Years, he would yet have made no more, than 14143750 Leagues. The Ball that goes through a Space of one hundred Fathoms in a Second, would make 60 Times as much in one Minute, that is, 180 Leagues every Hour. This would make 4320 Leagues a Day, and 1576800 Leagues a Year. Thus the Ball, after having continued its Motion for nine Years running, yet would have gone through but 14191200 Leagues.

D 2

If

* The Diameter of the Earth is 2864 common Leagues long, the Half-diameter being, according to the Calculations of the Gentlemen of the Academy of Sciences, 1432 Leagues, of 2282 Fathoms each League, which makes a Produce of 653,648 Fathoms: That is, at least, one million and a half of Fathoms more than we have chosen to go by, for the Conveniency of the Reader; which Calculation is the more certain here, on Account of the Measure being taken so little.

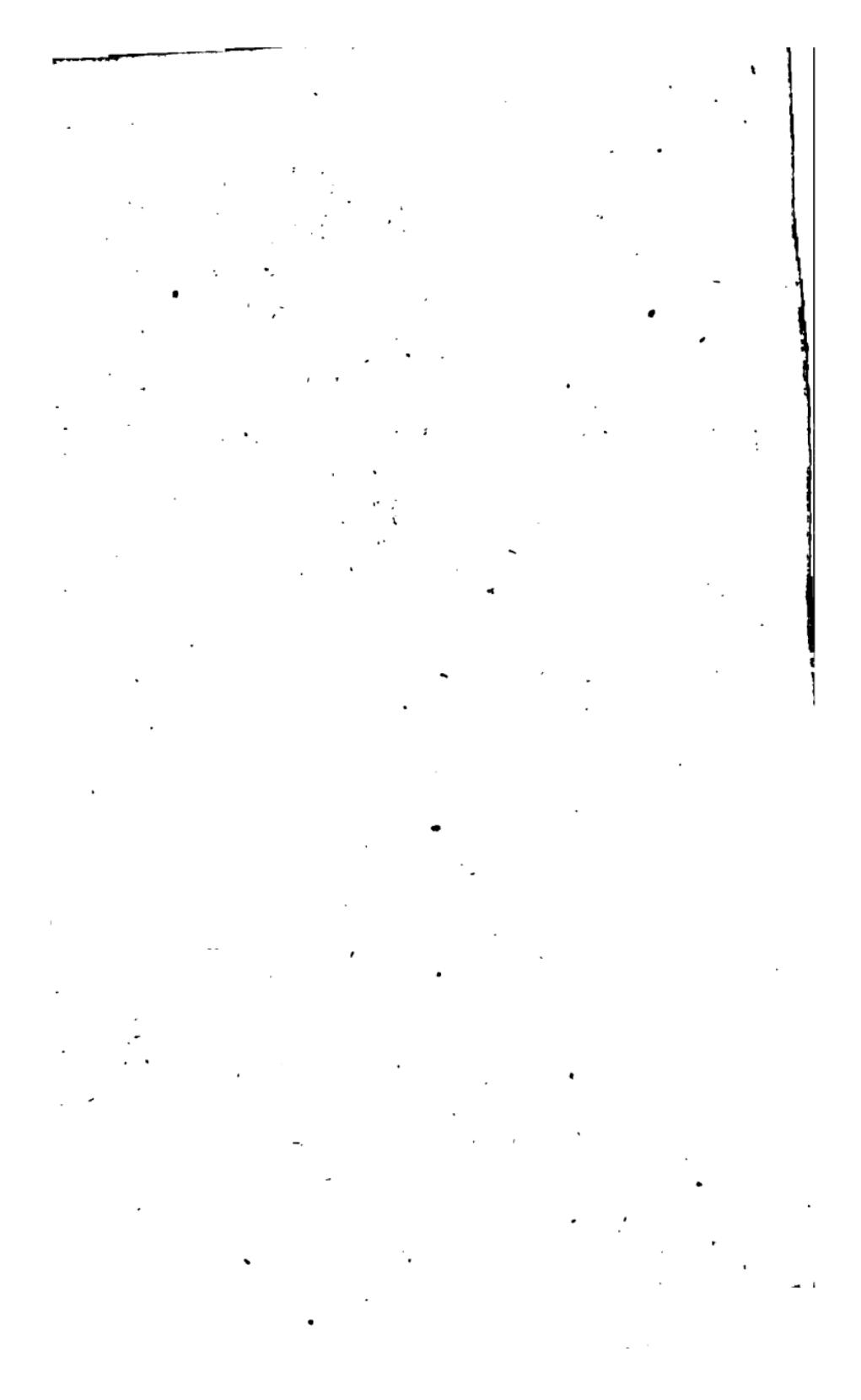
If nine Years are not sufficient to the Cannon-ball : If fifteen Ages and more, are not enough for the Horse to arrive at the Sun, according to our Calculation, which falls so very short, nay, which is not even Half of what is demonstrably known, and Matter of Fact ; at what Period of Time would they arrive, were they to complete the just Measure which escapes our Sight, and which may be considerably lengthened for one single Third or Fourth of a Minute, which neither our Eyes, nor any of our Instruments are able to take in ?

This Distance, which surprises us, is however very inconsiderable, in Comparison of that we afterwards shall find between the Earth and the Planet *Saturn* ; between the Moon and the fixed Stars ; between one Star and another.

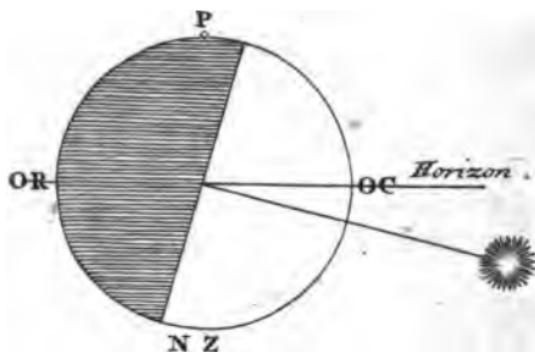
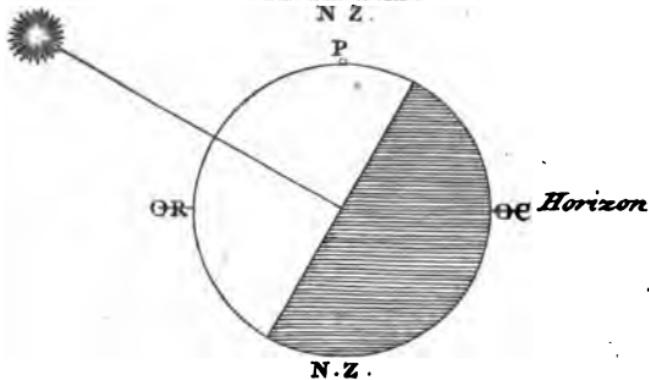
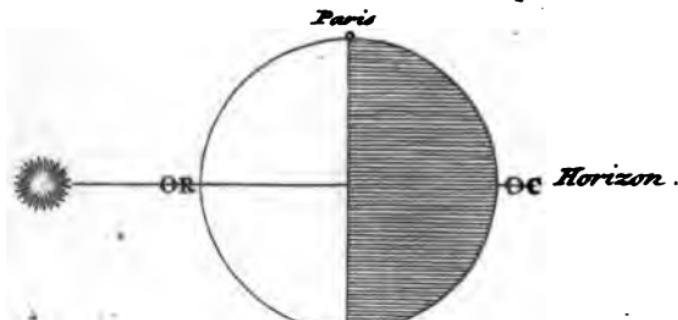
The Advan-
tages of that
Situation.

But that he, who dispenses Existence at his Will, and is absolute Master of Matter, should multiply, extend, enlarge it, and add a Kind of Immensity to his Works, is not properly what surprises me ; or at least my Amazement is chiefly founded on my own extreme Littleness. But what astonishes and affects me with much greater Reason, is to see, that notwithstanding this my extreme Littleness, a Hand, no less benevolent than masterly, has vouchsafed to regulate that Distance by the Advantages I was designed to receive from it, and has placed the Sun, with regard to the Earth on which I was lodged, at such a Distance, that it might be near enough to warm me, and sufficiently removed from it not to set it on fire.

The fiery Rays that proceed from a Globe of Fire, a hundred thousand, nay, a million Times bigger than the Earth, must needs have an inconceivable Activity and Force, so long as they remain close to one another, and act, as it were, in Concert. They afterwards must necessarily be divergent, that is, more and more distant from each other, as they advance from their common Center towards the vast Circumference which is enlightened by the Sun ; and their Force diminishes in Proportion to their Distance at the Extremities. This Divergency of the Rays of Light may be easily conceived from the Emblem of the Spokes of a Wheel, which are very



The Effects of the Sun upon the Horizon without an Atmosphere, the Eye looking towards the South.



Ja. Mynde Sculp.

close at the Nave whence they spring ; whereas towards the Fellows or Jaunts, where they end, they become more distant, as the Circle of those Jaunts enlarges.

Our Earth, had it been placed in a Point in which these Rays would have been still too numerous, and too near each other, could never have borne their burning Heat. Had it been placed farther off towards the Extremities of the solar World, it would have received from it but a faint dim Light, insufficient for its usual Productions. It stands in that very Place, where it is secured from all those Inconveniences which it had to fear; and within the Reach of all the Advantages and Blessings it could desire.

In vain should we pretend not to admire this fine Order, by looking upon the exact Situation of the Earth as a necessary Effect of Gravity, and of the mutual Attraction of Bodies. Those, who talk of Attraction and Gravitation, may possibly understand themselves : But did the Gravity, which if we grant regulated the Place of the Earth, form likewise the Atmosphere which surrounds it ? You already know the Artifice, Mechanism and Structure thereof : Another Observation will finish your Conviction, whether it is the Fall of a wandering Dust attracted or pressed, that has formed the Dust in the Place it actually fills, and thrown a transparent Atmosphere between her and the Sun ; or a special and perfectly Free-will, that has for the Good of Man regulated the Structure of the Earth, its Distance from the Sun, and the Correspondence of our Atmosphere with that Star.

Imagine with yourself the Earth to be exposed to the Rays of the Sun, as a Ball to the Light of a Flambeau. There can be but one Half thereof enlightened. Let us call the uppermost Point of the Ball *Paris*, or *P* ; and the undermost *New Zealand*, or *N Z* ; because the Southern Land is not very remote from the Point of our *Antipodes*. The two lateral Points, which are at equal Distances from the foregoing, we shall name *East* and *West* ; the one on the Left marked *E*, the other on the Right marked *W* ; and the Line that joins them, or that encompasses the Globe at an even Distance from *P* and *N Z*, let it be called the *Horizon*. - Being, as I am now, at the Point *P*,

which is the Center of my Horizon ; if the Sun was over my Head, the Half of the Earth, which it would in-lighten, would exactly be that which is terminated by the Line of my Horizon ; and the inferior Hemisphere would remain totally darkened. Now the Sun is rising, it is at the Point *E*, and remote from *P* by a whole Quarter of a Globe. The Half it lights, being the Width of two Quadrants, exactly terminates at *P* on the one Hand, and at *NZ*, which is near our *Antipodes*, on the other. Being at *P*, I then am on the Border of that Half which the Sun inlights. Its immediate Light ends and dies at my Feet, and at that Moment I can reach no farther. The Sun would otherwise light more than one Half of the Globe. The Border of the inlightened Half forms a Line that divides my Horizon into two Parts ; that on the Left towards *E* is wholly inlightened ; the other on the Right towards *W* must necessarily be totally dark ; so that at that Moment my Abode must be partly black, partly white. As the Sun ascends, the Line, which separates Night from Day, will incline farther towards the Right *W*, and there successively shew me new Objects. But when the Sun shall have got over the Point, at which it gives me Mid day, the more it shall decline to the Right *W*, the more the Half it lights will be engaged under the lower Hemisphere toward *NZ*, and the left Side of my Horizon will soon be covered by a horrid Darkness, that shall, till Sun-set, increase so as to take from me the Sight of one Half of the Horizon. But at the very Moment of its getting under the Horizon, all the Light I enjoyed from the Point *P*, or from my Feet to *W*, shall on a sudden be taken from me, since it can no longer reach to me. This must be a necessary Consequence of the immediate Irradiation of the Sun on the Earth. Why then does it not happen so ? If I freely enjoy the whole Compas of my Horizon, not only when the Sun has once glanced upon the Borders of it, but even a great while before it arrives thereat, and a long Time after it has withdrawn from it ; if the least Portion I can have of its Light is easily distributed through my whole Habitation ; to what am I indebted for such a Favour ? Is it to the Sun ? No : This can never inlighten more than what it sees, and there is no one Instant, at which

which it can see more than one Half of the Globe. Is it to the Nature of Light itself? Not at all: Its Motion is direct, and can light nothing in those Meanders, into which it penetrates not directly. The Atmosphere, which is placed between the Sun and the Earth, does alone produce this noble Work. It no sooner can bend the least Proportion of the Rays of the Sun on one Horizon, but it overspreads that Horizon with it. When the Sun itself arrives at that Circle, the Atmosphere prevents its Light from being divided there by Fourths or Thirds, or, as it were, sparingly distributed. It amplifies its Utilities: It is commissioned to improve its Favours, and not to suffer in any Part of the Garment wherewith it clothes the Earth, the unpleasant and discordant Sortment of the Night and the Day, drawn near and patched up together.

The Sun and the Atmosphere do then act in Concert for Man; and these two wonderful Instruments, though several millions of Leagues distant from each other, mutually, and with a kind of Intelligence, assist one another in the Distribution of the Day. Here you have no Attraction, or Gravity, nor any physical Cause that may have produced such a Work. Certain particular Laws might maintain, but could have never produced it. The Frame and Disposition of both these Pieces, so evidently made for each other, are owing to the same divine Will that placed Man within the Reach, Use, and Benefit of them.

We have already perceived the express and evident Will of God, in the Union of the Sperm and the Provision of the first Food, under the small Cover of the Egg of a Mite, or that of a Hand-worm. We found an express and particular Will and Determination, not only in the Structure of each Plant, but even in every the minutest Seed thereof. We find again the Character and Marks of an express Will, full of Tenderness towards us, in all the numberless Blessings which God multiplies from Year to Year, and from Day to Day, both upon and within the Earth. But with what Splendor and Magnificence does that Will shew itself in the Beauty of the Sun, and in the just Proportion of Size, Distance,

Action, and Usefulness, that has been established between that and the Earth.

God seems, without shewing himself as yet, with great Care to have united, in that noble Star, all the Strokes that might best represent to us the divine Perfections. Like God, it is single. The grandest and most glorious Objects seem to dwindle and vanish in its Presence. It sees all: It acts through all: It gives Life to all. Thus after the Earth has, in an infinite Combination of Manners, testified and demonstrated that Wisdom, which for our Sake did so liberally inrich every Part of it, the same Wisdom breaks out in the Heavens with an infinitely greater Majesty.

The Heavens, more especially, declare Psal. xix. the Grandeur and Glory of God. Nothing is more proper than the Firmament, to manifest God in his own Handy-work. Each Day commissions the following to declare God to us: Every Night to the following leaves the Care of pointing our Maker to us. The Instructions, which the Heavens afford us, are not a Speech or Language barbarous or foreign to us. They are not weak Sounds difficult to be heard. The Voice of the Heavens is familiar and intelligible: It is strong, sonorous, and unwearied: It reaches from the Heavens to the Earth: It is conveyed from one End of the World to the other: There is no Nation, nor Man on Earth, that does not understand it; the whole Universe is instructed.

But the Sun alone teaches us better, and affects us much more than all the Beauties the Heavens can display to our Sight. The Heavens are merely like a Pavilion * to the Sun. The Veils richly embroidered, which seemed to take from us the Sight of that Star, are removed when it advances towards us: They are withdrawn, and he alone remains visible. He is a young Bridegroom coming out of his nuptial Chamber, to shew himself on the solemnest Day of his Life. His Splendor is then full of Mildness. All admire him at his Arrival. All Eyes are fixed on him; and he makes himself easy of Access to them all, in order to receive their first Salutations.

But

* Hebr. *Soli posuit tentorium in illis (caelis.)*

But he is commissioned to convey the Heat and the Life, as well as the Light, every where. He hastens to discharge this important Office: He darts more and more Fires as he ascends: He passes from one End of the Heaven to the other, and runs his Race like a strong and indefatigable Wrestler: He enlivens whatever he lights. There is nothing that can either be hid from his Light, or subsist without his Heat; and by his penetrating Fires he reaches those very Places which are inaccessible to his Rays.

THE
PROPAGATION
OF
LIGHT.

DIALOGUE VII.

THE Operations of the Sun may be reduced to three. It inlights ; it colours ; it heats. It successively lights the whole Earth, that Man, and the Animals, which serve him, may walk in the Light of that Flambeau, when it casts it on them ; and go and take their Rest when it conceals itself, and no longer gives them Light. It not only inlights, but also colours the Objects : It distinguishes them, so that they may be known without any Confusion, Dispute, or Delay : In short, the Sun, besides procuring Light and Colours for us, conveys Heat and Motion every where, gives Life to Man, and perpetuates all the Supports of it which have been placed near him, both without the Earth, and within its Bowels.

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We mean not here to mention the more or less lively Sentiments which we experience from the Presence of the Sun, or of a great Fire. This, like all other Impressions, can no where exist but within ourselves. It is constantly dependent on what strikes our Eyes: But these are two different Things, one of which is a Consequence of the other. The same Sensation may subsist within us during our very Sleep, and independent of any outward Impressions. Our Searches run solely on corporeal Light; on that Substance which affects our Eyes, and whose Impression is followed by another, which affects the Soul, and informs us of the Presence, Disposition, and Form of Objects. The Causes of that Light wherewith God influences our Souls, and that of the Light which affects our Eyes, seem to me equally superior to our present Understanding. But as God is pleased to let us know, at least by inward Sense, a Multitude of Truths concerning the Nature of our Souls, and its Affections, without granting us the Knowledge of all the rest; he likewise is pleased to shew us a Part of the Workmanship, wherewith he, for our Sakes, puts the outward Light in Motion. Let us then eagerly lay hold of what we are allowed to know of it. Our true Happiness, even in this present Life, is to become grateful, in Proportion as we advance in the Knowledge of God's Ways. What then shall we be, when we see Light in the Bosom of Light itself?

Nothing is plainer, nothing more agreeable to Scripture, to the History of the Creation, to Reason and Experience, than to look upon Light as an intermediate Fluid, which not only extends from the Sun to us, but also fills the whole Universe, and without changing its Place by a successive, though extremely swift Pressure, conveys the Action of our Sun to the very Sphères of the Stars, as that Fluid transmits the Impression and Sight of the Stars themselves in the Sphere of the Sun.

The Wave of a River communicates, to a great Distance, a single Impulse, or one several Times reiterated. The Undulations of the Air carry still quicker, and in all Directions, the Motion caused in that Air. Hence every one will easily believe, that a thinner, lighter, and

60 DIALOGUE VII.

more active Fluid, (let the Nature of Fluids in general be what it will) may in a few Minutes convey the Impulse of the solar Matter, which presses it, very far, and render the Presence and Influence of that Star sensible at prodigious Distances.

The Body of Light, conceived as an immense Liquid, always surrounds us, but is not always pushed down to us. It is only constantly ready to serve and inform us, at the very first Shock it shall receive from the Sun, from a Conflagration, a Flambeau, or a single Spark. That Fluid is, indeed, pushed by the Sun, and by all inflamed Bodies, but is neither the Result or the Effect thereof. The Light then may have been created before the Sun, and the Stars as it were have been immersed in it in such particular Situations, as to make them correspond by the Communication of the Motions they cause therein. Thus all the Spheres are involved in Light: There they swim or roll according to the Limits prescribed and appointed them. The Light retains them all in their Places, and makes them visible and useful to each other. Shall we then wonder at *Mosés*'s beginning the Recital of God's Works from the Creation of the Body of the Light, of that immense and equally precious Substance, in which the Sphères were to make their daily and annual Revolutions, and which was to be the Basis, or rather the Bond, of all the Parts of the Universe?

But might we not have some reasonable Conjecture on the Nature of Fluids founded on Experience; so that by the Application which may be made of it to Light, the understanding of the Effects it produces might be rendered easy and intelligible to us?

The Nature of Fluids. It is plainly remarked of all Fluids, as Water, Oil, melted Metals, and others; First,

That all the Parts thereof are disunited; that they easily roll over one another, and are always ready to yield to the first Impression. Secondly, That all these Parts have a certain either inherent or borrowed Activity; which causes them mutually to press each other every Way, as if they were so many small circular Springs, always inclined to dilate or fly out on every Side; so that as much as one pushes the other, by so much it is reciprocally pushed thereby; the Force of each of which being

being equal, they counterbalance each other, and remain all in a perfect Equilibrio.

This second Property of Fluids is the most essential: It is that which distinguishes them. A Heap of Corn, or of Sand, as well as one of Water, is made up of separate Parts, which easily yield to all Impressions. They, nevertheless, are no Fluids; because the Parts, of which they consist, have no Sort of Activity to press each other every Way. Do you force your Hand into a Bushel of Corn or Sand; the Grains are removed on each Side. They have a certain Gravity which precipitates them downwards, so long as they are not supported: But they no sooner rest upon one another shelving, as it were, but they remain at Rest, and have no Manner of Force again, to get into and fill the empty Place that has just been impressed in the Mass. It is otherwise with Fluids. If you put your Hand, or a Stick down to them, that will be a Pressure and extraneous Force, which comes more or less to discompose the Equilibrium of that Fluid. The first Parts that are pressed bear against those that are next to them all round. These having a Motion greater than before towards one certain Part, share it with those which are farther off on the same Side. This Motion actually being, or always inclining to be made in the Way of a Vortex, communicates itself all round and every Way; and this orbicular Communication extends very far, because one Particle impels two others next to it. These two strike against four that are more remote, and the four push the eight that follow. What we see done on one Side, is at the same Time done on all others; and thus the Equilibrium of the whole fluid Mass is discomposed by a single extraneous Shock. But this Discompose always lessens in Proportion as the Number of the Particles, among which it is divided, increases. On the other Hand, the natural Activity of those Particles, (all which I for a Moment suppose to have a Spring acting every Way) meeting with a Resistance still greater and greater, and less Liberty on the Side towards which they are pushed, they are immediately repelled by others, and repressed themselves, both by their own Elasticity, and by the contrary Efforts of the whole fluid Mass tending towards that Place from which they were first removed.

But

But how shall we conceive that the Particles of a Fluid have a Spring acting every Way? If they tend one Way, it is progressively: How then is it possible they should tend towards the opposite, and every other Side at the same Time? So soon as they are pushed towards one Place,

See La Recherche de la Verite, Vol. IV. Ecol. 16.

must they not of Course recede from all the rest? Father *Malbranche* has supplied us for that Purpose with a Piece of Mechanics, very plain and agreeable to the Action of all Fluids; *viz.* to conceive all their Particles,

See the Physical Lectures of M. Privat de Molieres.

as being so many small Vortices particularly rolling on their own Axes, and made up of other Particles, that endeavour in circulating to deviate from their common Center.

It would not be sufficient with Mr. *Descartes*, to conceive the Parts of a Fluid, and those of Light in particular, as so many small Globes, or as hard and inflexible Whirligigs, lightly circulating on their own Axes. These being inflexible, and without any Elasticity, would likewise have no Manner of Influence on each other; because the Particles, of which they are composed, are at rest among themselves, and strive not to separate. Lines made up of these hard Globules ranked together, would be like a Stick, which being struck at one End, at the same Time is struck at the other. And this is contrary to Experience, which shews, that the Progression of Liquids and of Light is successive; whereas, if these Globules of Air, of Fire, or of Light, are themselves made up of other disunited Particles perpetually whirling round an Axis or a Line that may be imagined in them, it will be an easy Matter to conceive how these Spherules mutually push each other, in striving to dilate themselves, and to widen every Way.

Experience shews, that any moved Body has always a Tendency to advance in a strait Line, unless it be diverted and driven aside; and never follows a circular Line, but from the Constraint put upon it by the surrounding Bodies, which perpetually force it out of the direct Line. This may be proved by two Instances. When a Child puts a Stone in a Sling, he no sooner sets it in Motion, but it shall perpetually endeavour to fly off from the Hand that gives it Motion. It will incessantly, and with very great Force, push against the Bottom of the Sling: It will stretch

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the Strings ; and as soon as one of them is let go, the Stone will get away in a Line, which would be strait, did not Gravity perpetually alter the Direction of it.

When a Singing-boy puts Fire into his Censer ; as soon as the Machine with the Coals are in Motion, instead of falling through the Holes or on the Cover, which is often in swinging turned downwards, they on the contrary tend upwards, when the Censer rises : They press against the Bottom of it, and perpetually endeavour to recede from the Hand which is the Cause and Center of their Motion.

If then the Particles, of which the Globules of a Liquid consist, have all an Inclination to recede from their Center, they will be moved circularly, for Want of Power to follow the strait Line, by reason of the mutual Obstacle they are to each other. They will perpetually endeavour to part from, and mutually strike against each other. From the mutual Pressure, and Equality of the Force of all these Globules, must needs follow an universal Equilibrium among them. Hence proceeds the orbicular Impression of every Motion that chances to trouble that equal Balance : Hence the Resistance of the whole fluid Mass : Hence its returning towards the Place from whence any of its Particles have been removed.

Thus we may easily conceive, why a Drop of Water, Mercury, melted Gold, or any other Liquid, always takes a spherical Form. All the Particles of that Drop have an Inclination to recede from each other : But the equal Pressure of the encompassing Air detains and forces them to move in a circular Line : Therefore it is they gather in Form of a Ball. Hence we understand, why two Drops of Liquor no sooner touch each other, but they gather in a single Drop. Though these two Drops should touch one another only in a single Point, they presently would become flat, and press each other in that Point. Herein the Circulation of the Globules is broken and constrained. They therefore endeavour to recover the Freedom and Action of their Spring. Their Action is not direct, because they meet with a Resistance in the Thickness of the Drop, not to be overcome ; whereas they are less resisted towards the Intervals that still separate the two Drops a small Matter. All the confined Globules will then tend toward these empty Spaces, where they find least

least Resistance. They will at last fill them so, that the Motion, which is universal in the two Drops, will be made in a circular and uniform Manner, by the circular gathering of the two Bodies into a single one.

Thence we may conceive, that as a Vessel presses on the liquid Mass which is under it, so all the Globules of the Liquid press, and reciprocally act against the Vessel; and this floats on that without sinking, when the Force, which makes the Vessel heavy, and that of the resisting Liquid are equal and in Equilibrio. We may in the same Manner conceive the Reason of the Rarefactions or Dilatations of a Fluid; as of boiling Water or Coffee, or of frothing Wine. There is another more active Fluid, as Air or Fire, which has insinuated itself into the Intertices of the Globules of the first, and sustains or even disperses them by the Superiority of its Force.

Thence again may be deduced the Reason of the Dissolutions, Ebullition, and Effervesences, that happen by the Mixtures of some cold Liquors, Salts, and other Matters. The Activity of the Vortices is different in every liquid Body. The Excess of the Strength of some over that of others, may therein occasion a rapid Motion, that will lessen in Proportion as the whole Mass shall come near to the Equilibrium. And the Activity, which is inseparable from them, shall render them capable of separating some Salts or certain Metals, and of sustaining a certain Quantity of them on the Circumference of the Globules.

Now, if we apply this Structure of Fluids to the Light, we may conjecture, that the Matter, of which the Sun is made, being the most active of Bodies, that large Globe, by revolving on its own Axis, and endeavouring to dilate itself on every Side, or perhaps in darting its Flames from the Center to the Circumference, and bringing them back again from the Circumference to the Center, shocks, strikes against, and perpetually scatters on every Side the vast Fluid of Light which surrounds it; and that the Strokes, which the Light receives from it, are felt at the very Spheres of the Stars; making thus on all Sides an inconceivably swift, though successive Undulation. We easily conceive, that the Force of that Pressure always lessens in Proportion to the Distance; and consequently,

that

that the Light acts much more powerfully on the Planets, nearer to the Sun, than on those that are more remote from it ; and finally, that the universal Resistance of the Fluid, to the Strokes of the solar Fires, makes it perpetually flow back towards the Sun, that continually pushes and is reciprocally pushed by it ; which keeps the Sun in the same Place, and hinders it from wasting.

Sure there is in this Structure as well as in the Action of those Fluids, an Artifice infinitely superior to these poor Conjectures. But they nevertheless help us, in some little Measure, to be conscious of a Truth equally affecting and certain, *viz.* That if these Powers, instead of mutually destroying each other by their terrible Clashings, do on the contrary preserve, maintain, and counterbalance each other, in a Manner which conveys Order and Beauty every where ; of Course there is no one single Particle in those Fluids, but what has been weighed in a Balance, in order to proportion and adapt its Shape to the adjacent Particles. None but what has received a determined Form, its exact and precise Measure of Activity.

Now let us see what the Mass or Bigness of an Atom or Globule of Light may be. The Creator having designed to take the Dimensions of it, what we may conceive thereof, well deserves that we should bestow a little of our Attention upon it. You easily judge of the Difference there is betwixt the Body of the Air and that of the Water, from the Difference of their Waves : And as the Vibrations of the Air or Sounds are communicated several hundred Times quicker than the like Agitations of the Water ; we thence conceive, that Air is several hundred Times thinner and more active than Water. If then Light, as Experience shews, crosses a Space of six hundred thousand Leagues almost as quickly as Sound traverses over two or three thousand Fathoms ; the Globules of Light must needs be six hundred thousand Times finer and more active than a Particle of Air, which nevertheless escapes our Sight, though assisted by the best Microscopes.

The Shape of
the Globules,
or Atoms of
Light.

But let us leave off Calculations, always tiresome, and oftentimes uncertain. We have a much plainer Method for

for measuring a Particle of Light. Observe in the Microscope one of those Animals which are found in Water, in Summer-time, after one has infused Pepper therein, or Flour, or any Plant whatever. In a few Days, the Eggs of those Insects are hatched therein, some of them being already on the Plants or Fruits put in the said Water to be dissolved, and others being laid in the Water by the Mother, which searches in the Air and by the Help of smelling for a proper Place to lay them in. These minute Worms are very often a thousand Times smaller than the most imperceptible Mice; since the Microscope shews us thousands of them in a Drop of Water, which is smaller than the minutest Grain of Sand. What can be the Size of such an Animal? What the several Fluids of which his Eye is made? What will the fore-shortened Image of the Objects represented in the Bottom of such an Eye be? Now that Image is made up of the Extremities of an infinite Number of Rays of Light. What then can be one Globule of that Light? And if each Globule is a Vortex made up of small Particles, which all have an Inclination to distend themselves every Way, and which losing a little of their Equilibrium by an extraneous Pressure, cause at the Bottom of the Eye of that living Creature a Vibration proportioned to its peculiar Wants; what is this but an Abyss of Diminutions in the Forms of Elements, as well as in those of compound Bodies? An Abyss of Proportions in the Motions that are least understood, and of Wonders in what is hidden as well as in what is perceived.

How much soever beyond the Reach of our Senses, the Structure and Dimensions of the small Particles of Light may be; yet may we make some tolerable Judgment of it, by comparing its Action and Effects with those of some more perceptible Elements. There are indeed in the Works of God Differences that characterize them all: But there is at the same Time a Ground of Analogy, which intimates the Unity of the Artificer. What a Variety is there in Animals? Nevertheless, they all have a Heart, a Quantity of Blood, a Stomach, Lungs, or Parts equivalent. What a Variety in Plants? Yet all have a Seed, and Farinæ, or vivifying Dusts, to make those Seeds fruitful. All animated or living Bodies differ in some

some Particular: But at the same Time they all agree in the Main, by some Kind of Resemblance; and wherever that is wanting, we judge, and are sure, that it is no longer a living Creature that we behold. We therefore are in the Way of Truth, when observing Light to act in the Manner of Fluids, we suppose it to have some Resemblance with other Fluids. And as nothing has as yet seemed more proper to account for the Equilibrium of Liquors, than to consider their Particles as so many Globules, which mutually press each other, by the Equality of the Efforts which each individual Particle of those Globules makes, in order to recede from the Center round which they revolve; by this Means we may frame to ourselves a Notion of the Nature of Light, and thence deduce the Manner in which it is communicated.

If you put a Wall, or any other gross Body, in the Way of Sound or Air agitated by the Voice, the Air is stopped and there reflected. If you oppose a Wall, arched according to certain Rules, to the Sound of an Instrument, several Lines of Air, that shall be reflected from the several Points of that Bend, will meet in one and the same Point; so that the Ear, being exactly at that Point, shall hear eight or ten Violins instead of one. * The Wave that is formed on the Surface of the Water of a Pond, meeting a Pier, Bank, or any other Obstacle, is stopped short there. It then shrinks back, and retires on itself, and the Portion of its Circle, which remains imperfect, and as it were cut by the Bank or Pier, is completed on this Side, and in a contrary Direction, though in a weaker Degree, occasioned by the Resistance of the Wall whence it is reflected. The Emotion of the Air and the Water communicates itself a small Matter into the Windings, and behind the Bodies opposed to the direct Line; but this Emotion, being diverted and changing its Direction, soon after becomes insensible. In short, every Fluid, which receives any Impulse, or outward Pressure, loses thereby a Part of its Equilibrium, and the Agitation caused therein is distributed through the whole Mass, spreading on every Side. But as the said Agitation is, as it were, more strongly felt by the Particles

* The same Thing may be observed in the Court before the Castle of Genette, a Place two Leagues distant from Roan in Caur.

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Particles which are first moved, and always less and less by those that are the remotest, the Communication of that Impression at first is stronger, then weaker, and diminishes in Proportion to the Degree of their Remoteness, and of the Windings that break the direct Impulsion. Nay, if several Motions are at once given to the Fluid; if you give it several reiterated Blows, and in contrary Directions; all these Waves will perhaps intersect and mutually weaken each other, but never be blended or totally destroyed.. All the Noises and Cries of any public Place reach the Ears of all those that live near it, and all the Voices, whether strong or weak, in a Concert, strike the Ears of every Listener. But the most predominating of them is always distinguished, as the briskest Bow of the Concert is heard above the rest. The very smallest Impulse, caused in the Water of a River, shall regularly be distributed all around, and the largest Waves shall not be more real for their being better perceived.

Thus the fluid Body of the Light being (though in an infinitely more active and swifter Manner) struck by the enormous Shocks of the Sun whirling on its own Axis, receives from it such an Agitation as reaches to the very Spheres of the Stars. But to the End that this Fluid may appear there what a Star appears here below; that is, to the End that one Stroke of the Sun may carry its Impression far beyond several thousands of millions of Leagues, the first Motion of such a Wave must needs be of an inconceivable Violence near the Body of the Sun. This Motion of the Light, compared to the higher Billows of the Sea, must needs be what the foaming Sea itself is, in Comparison of a Pond, whose Surface ripples under the Breath of the gentle Zephyr.

But here I am greatly mistaken. The slight Depth of the Ridges which that gentle Breeze has impressed on the Water of the Pond, and the Height of the Surges which the Sea tosses on high, may be measured and compared together: But when we are to measure the Distance between the Sun and a Star, or to calculate the proportional Decreases of Light from the very Beginning of its Waves, to the Places where they cease to act; it is then that Geometry and Arithmetic fails us. But then these were given us to measure round us merely those

those Things that bear any Relation to us, the Proportions and Limits of which may be found.

This conjectural Explanation of the Nature of Light is, methinks, the more delightful, because it is grounded upon the uniform Conduct, which God has observed in the Action of all Fluids: It is agreeable to the Effects of Light; and nothing seems to me more capable of rectifying the Mistakes we almost all of us fall into, on the Nature of that wonderful Element.

We have, in our Infancy, contracted a false Notion of the Light, which we have much ado to get rid of in an advanced Age. As we see Objects, without perceiving any Thing between them and us; the whole Interval, which separates us and them, appears to be nothing but a vast Vacuum, and we fancy that our Eyes have of themselves the Power of seeing what is before us, without the Necessity of having any Body to be pushed or reflected from these Objects toward our Eyes. Much less do we suspect that Space to be filled with a Substance sufficiently active, to be reflected from every Object towards every Eye which shall present itself; fine enough to penetrate through them, and distributed, as it enters them, with a Regularity sufficient to form any Picture therein. But though this Error be but of small Consequence; yet the Intention of him, who created the Light, not being that every one of us should inquire into the Nature of it; but rather, that we should use it with Gratitude; yet when we sit down to review our first Notions, and endeavour to judge of Things as rightly as we can, then have we a thousand Ways to contract this innocent Mistake.

We naturally, and without the Help of much Reflection, are presently convinced of the Existence of the Air; and we acknowledge the Reality of it, because we hear the Noise and feel the Impulses thereof; though an infinitely wise Oeconomist has placed, beyond the Reach of our Sight, the Particles of the Air which surround us. So is it with the Body of Light, which, though incomparably finer, yet is it no less easy to know, with full Certainty, the Presence, and Extent, and Properties of it; since the Difference of its Way through Air and Water may be discerned, and since we can exactly mark the several

several Points which the Light shall arrive at, in passing through a triangular Prism, or a hollow Glass, or through a lenticular Mass of the same Matter. Must we not therefore be convinced that our distinguishing the Motions of Light, our making use of its several Progressions, and our prescribing even the exact Point on which we would have it fall, is to us a great Assurance that it exists round us, and is at our Command?

Another Mistake, which we have already prevented, is to believe that Light reaches us by a local Motion, or by its real falling on the Object, and on the Eye; so that the Rays, which, for Instance, make me discern (when I am on *Pont-royal*) the Figure of King *Henry IV.* on Horseback in the Middle of the *Pont-neuf*, must have crossed the whole Space between the Sun and the said Figure, and then by a second Transportation must have reached my Eye from Bridge to Bridge.

No. The Thing is quite otherwise effected. We live in the Fluid of Light, as Fishes do in Water. When nothing agitates the Water, the Fish never feel it: So when nothing agitates the Light, neither do we feel it. But how comes it, that the Fall of the Net, which a Fisherman has just cast, has put to flight a Fish, which was far enough from it? Have those Parts of the Water, which the Fisherman has struck, been transported from Place to Place as far as the Fish? Not in the least: But the Pressure on these has destroyed the Equilibrium of those that were more remote. These again have struck against the following, which have shocked others; and the News of the Danger has thus reached the Fish, not by the Transportation, but by the Pressure of the Particles of the Water. When therefore we say, that from the whole Mass of the Atmosphere, a Multitude of Rays of Light fall on the Head of King *Henry IV.* and that these Rays which come upon it from all Sides, dashing every Way therefrom, cross the Air, and traverse the Eyes of the Spectator, it is an improper and incorrect Way of speaking, authorized however by Use, and which, being reduced to exact Truth, must be understood of a quick, though successive, Pressure made in the Fluid, without having the Parts of it considerably displaced; and this Displacing is less in Proportion as the Remote-

ness of the luminous Body is greater: Just as we see the Water strongly agitated under the Oar of the Waterman who moves it, which a great Way off finds but a gentle Shock, lessening every Moment. It is by these Lines of Pressure, either immediately proceeding from the luminous Bodies, or reflected from the Objects, that we maintain a Correspondence with what is about us upon Earth. By the Help of these Lines pushed from above, and reflected from the Point of a Needle, as well as from any Platform, twelve or even a hundred People, shall be able to receive the same Point, from several Places, at one and the same Time. It is by such Lines that we have a Correspondence with the Stars, and with the whole Heavens. The Activity of that Pressure, which has its Original either in the Stars, or in some flaming Body, is distributed into large Waves, which are cut by all the Points of every Object that happens to cross their Passage. The Portion of that Wave, which is reflected on a Point, is communicated round about, and as it were unravelled into other small Rays, each of which meeting with some new Object, suffers a new Division. All these Reflections and Attenuations are sensible in the Light, and convince us of its perpetual Presence, and of its extreme Mobility. It subsists always the same: But the Pressures, it has undergone, always lessen from one Reflexion to another, by new Subdivisions, as from *A* to *B*, from *B* to *C*: And when at last it is restored to its State of Equilibrium, it then has no longer any Influence over us. It surrounds without striking us, and is no more than Darkness.

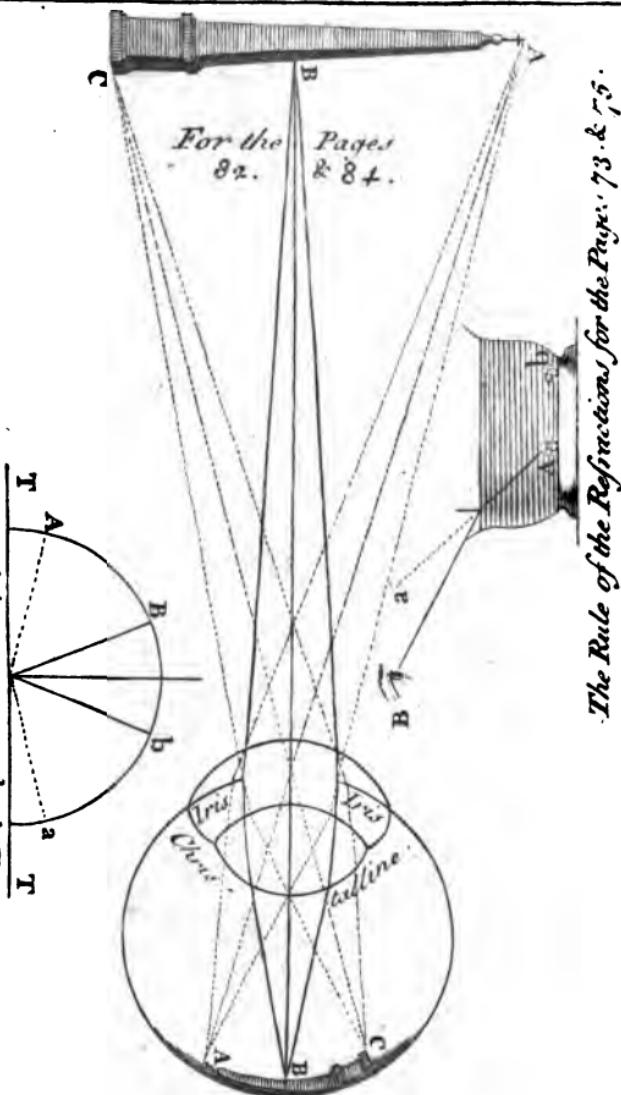
THE
WAYS of the LIGHT,
AND THE
WONDERS of VISION.

DIALOGUE VIII.

HAVING thus made the requisite Distinction between the Impulsion of the Fire of the Sun, and the Activity and Spring of the vast Fluid of the Light; let us now unite what we before divided: Let us now make them concur, and for the future look upon these two as one single Agent, whose several Impulses, acting every Way in strait Lines, may be properly distinguished by the Name of Rays.

All these Strokes rapidly continue, and perpetually repeat the same Course towards the Extremities of the Sphere. They even reach to the Spheres of the other Stars, but are attenuated in the Immensity of the Spaces they go through, and at last are extinguished or absorbed by the superior Impulsion of those other luminous Bodies. If they meet with any masty Bodies that cross the Lines of their

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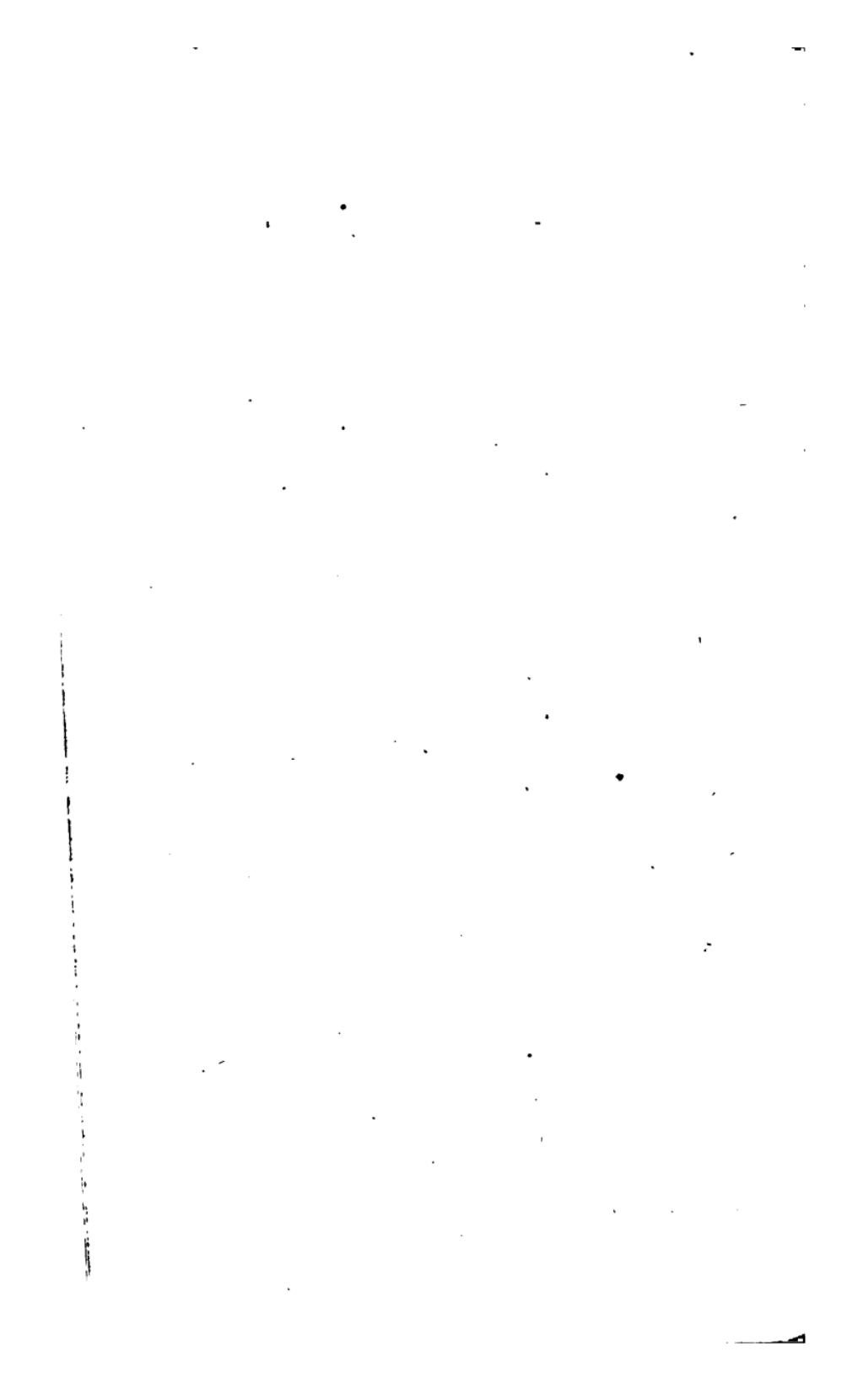


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their Directions, then it is, that these Rays produce the great Effects for which the Creator incessantly sends them : For they either are reflected, that is, sent back by these Bodies, and shew them us more or less luminous ; or they pervade, pass through, and render them transparent ; or in a Word, they are absorbed by them, and lose their Direction there ; so that these Bodies remain in their natural State, that is, opaque, or without Light.

There is no one Body, whether fluid or fixed, that does not partly reflect, and partly admit the Light. All Bodies are made up of Parts divided by Pores, and of impenetrable Elements. All is not porous in them ; and after the smallest Pores, which we shall call the least Order of Pores, there are of Necessity some solid Parts, that will stop the Passage of the Light. It then shall be partly admitted into certain Apertures, proportioned to its Size or Form, and partly stopped by the solid Parts, on which its Spring being pressed cannot but return. But it not only bounds on impenetrab'e Parts ; it may be as much, and perhaps, more abundantly reflected by the Fluids, that may chance to be on the Surfaces within the Pores and Interstices which divide the solid Parts. For Instance : If Fire was a fluid Element distinguished from Light (a Point which I do not examine at present into) when lodged in massy Bodies, it would be very apt to cause Light to be reflected there, necessarily repelling one Spring by another. The Air, whose Elasticity is so well known, may in its Turn contribute to the same Effect. Water, Oil, and other Fluids that are dispersed through all Bodies, may as well, and perhaps better than the solid Elements, multiply the Reflexions of Light ; and the Benefit of that Reflexion consists in its rendering Bodies visible to our Eyes.

The most compact Bodies, such as Salt, Crystal, and Diamonds, are wholly interspersed with Pores, and must every Way admit so fine a Body as that of Light. But whenever Light passes out of a solid Body, the Particles of which are in Repose, into a Fluid, as Water, or into an Elastic, as Air, it changes its Direction. The same happens, when it passes from a fluid into a hard Body, or even

from one solid into another of different Make and Structure. The Ray is there bent, and deviates more or less from its Direction. This Bending is what they call **Refraction**; and to convince you of the Variety of the Ways, which Light takes in passing through new Mediums, I shall propose to you no other than the two most common Instances, and those most exposed to every Eye. Pray, call to Mind the Form which a Stick half dip into the Water assumes. It seems broken; because the Rays, that return from the immersed Part of it, coming into the Air; follow not the same Direction they had in the Water. You may likewise remember, that when you draw back from the Rim of a *China* Bowl, till you can no longer see the Flower-basket painted at the Bottom in *A*, should any one pour Water into the Bowl, though you do not change your Place, you then plainly see the Flower-basket in *b*; and the Water shall be no sooner sucked up with a Reed, but the Basket shall again disappear. When the Water is gone, you see the Basket no longer; because the Rays that go from it to the Borders of the Bowl, pass above your Eye in *a*; whereas, when the Water is in the Bowl, the Ray, passing from the Water into the Air, bends and is lowered so, that it meets not the Top of your Forehead, as it did before, but your Eyes, which then perceive in *B* what is in Reality hidden, with regard to them, behind the Edges of the Bowl.

A Desire of bringing the important Services of Light to Perfection, has caused Men carefully to study the **Reflexions** and **Refractions** of it. They have explored all the Paths, and the most delicate Variations of it, and found out, either in the Boundings, or in the Bendings of the Light, Rules so constant and steady, that they have been made a most certain Science, and an Art productive of a thousand useful Contrivances. To this Study we are beholden for the making and cutting of Looking-glasses, of Jewels, or of Glasses cut facet and table-wise, hollow, relieve, &c. of reflecting and refracting Telescopes, and of an amazing Multitude of other Instruments fit to assist Astronomers, and the common Use of Sight. As Optics is no less engaging, by the Clearness of its Principles, than by the Excellency of its Effects; I have it at Heart, one

Day or other, to collect for you the finest Parts of it: But the Order of our Discourses obliges us, for the present, to be contented with the two Laws which Light invariably follows, which are the Foundation of the most curious Things that can be said about it, and of which we may be informed by the bare Testimony of our Senses. The one belongs to Reflexion, and the other to Refraction. In both Cases, an imaginary Line is supposed to fall perpendicularly on the Surface of the new Medium into which the Light enters.

The Rule of Reflexions consists in knowing, that Light, falling perpendicularly on a Surface, returns again from it in a perpendicular Line: But that, when it falls thereon obliquely, it bounds back from it on the contrary Side with the like Obliquity from *B* to *b* and from *A* to *a*: Or, which is the same Thing, that the Angle of Reflexion is equal to the Angle of Incidence.

The Rule of Refractions consists in knowing, First, That Light, which enters a Medium perpendicularly, suffers no Bending there, and proceeds onward according to the same Direction. Secondly, That when it passes obliquely from a rarer Medium into a denser, it deviates a small Matter from this Obliquity, as it goes through the Body of the Medium, and inclines towards the Perpendicular. Thirdly, That when it passes from a grosser or denser Medium, into one that is less compact or more rare, as out of Glass or Water into the Air; it deviates from the Perpendicular, and inclines a little to the Surface of the lighter Medium. We shall perhaps, one Day or other, look into the physical Reason of these two Rules, and the Reason why the Refraction of Light is just the Reverse of that of solid Bodies: For a Stone, obliquely thrown into the Water, deviates therein from the Perpendicular, inclining a little towards the Surface; whereas, when obliquely flung from the Water into the Air, it deviates a little from the Surface of the Water, inclining towards the Perpendicular. But all that can be imagined, on the Reasons of these Motions, will never be either so sure or so satisfactory as these two Principles, which are Matters of Fact. The Application of them

takes in all that is sufficient for us to know, in order to vary the Uses of Light according to our Wants.

The Cause of Opacity. Here the famous Question of the Opacity of Bodies naturally offers itself. What can be the Cause thereof? It is already difficult enough to conceive how a Body, so hard and so compact as a Diamond, is every where open to admit the Light. But it is much less conceivable how Wood, so porous as Cork, is not a thousand Times more transparent than Crystal. It is no less difficult to give a Reason, why Water and Oil, which both are transparent singly taken, lose their Transparency when they are beaten together: Why Champaign Wine, which is as bright as a Diamond, loses its Splendor, when the Bubbles of Air dilate, and raise a Froth within: Why Paper is opaque, as long as it has in its Pores nothing but Air, which is naturally so clear, and the same Paper becomes transparent, when its Pores are filled with Water or Oil.

Almost all Men, and Philosophers as well as the Vulgar have a Frejudice, that a Body is opaque and dark, because it does not admit the Light into its Pores, and that this Light would appear therein, did it go through it. But let us renounce this Error. The first Elements excepted of which Bodies are made, there is not perhaps a single Body in Nature, but what is accessible to and penetrable by the Light. A Spherule of Air will yield a Passage to it, provided it does not enter too obliquely. It goes through Water and other simple Fluids. It penetrates the small Laminæ of Gold, Silver, and Copper, which are divided and sufficiently attenuated, to be in Equilibrio with the corrosive Liquors in which they are put to dissolve. Bodies which appear the most simple to us, as Sand and Salt, are transparent. Even Bodies which are a little compound, easily admit the Light, in Proportion to the Uniformity and Repose of their Particles. Glass, Crystal, and above all, Diamonds, are Compounds of hardly any Thing but fine Sands, and of a few more or less fine Salts. Wherefore they are a very little Obstacle to the Passage of Light. It is otherwise with a Spunge, a Slate, or a Piece of Marble. All these Bodies which we call opaque, when between the Sun and our Eyes, admit indeed the Light, like so many Sieves: But they divert it, they

they blunt it, and sensibly hinder it from reaching our Eyes. What then is there in them, which can cause in Light an Alteration it does not undergo in infinitely more compact Bodies? This Disorder, if it be one, proceeds from the Variety of the Pores, and the Diversity of the Principles of which the Body is compounded. Recall to your Mind what we just advanced; that Light, when it falls on a Surface, is partly admitted, and partly reflected from it. Secondly, you know that it bends many different Ways, in all the various Mediums it passes through. Let us begin to apply our two optical Rules. The first Benefit, we shall thence receive, will be a very plain Explanation of the Opacity of Bodies.

If a Body be made only of uniform Particles, as Water and Diamonds are, the Portion of Light admitted therein shall in an uniform Manner pass through the Mass of that Body. There are the same Particles every where, and every where the same Disposition of Pores: That Path shall constantly be the same to the opposite Extremity, where the Light may afterwards sensibly come out.

But if the Body, which the Light enters into, is made of very dissimilar Particles, such as the Laminæ of Sand, of Lemon, Oil, Fire, Salt, and Air; the Globules and Laminæ of these Elements being of a different Density, and of different Situations, the Light bends and is reflected very variously on them. It deviates from the Perpendicular in entering into a Particle of Air, and inclines towards the Perpendicular, when it enters into a Lamina of Salt. The several Obliquities of the Surfaces it enters from one Instant to another, are a new Source of Meanderings and Attenuations. Even the boring of a Body with a great Number of Holes in every Direction, is sufficient to make it lose its Transparency. Jewels lose theirs in a great Measure; Fire makes a Kind of Sieve of them; because Light suffers there too many Reflexions, and winds upon so many Surfaces, all differently inclined; whence it happens, that it cannot in an uniform Manner go through and reach the Eyes of the Spectator.

Opacity proceeds then from the Disorder of the Reflexions, and from the Windings of Light, occasioned by the too great Variety of Pores. Of this you have a well-known Instance in Coals, in which the Fire makes millions of

Passages, which the Microscope renders visible. A Coal admits into it much more Light than the Diamond: But it diverts and absorbs that Light in the Pores, and on the numberless Surfaces opposed to it, which break it within the Mass, instead of reflecting it truly towards the exterior Surface, or of transmitting it, in a regular Track, to the opposite Extremity. Hence it appears, that there is no Body, that receives inwardly so much Light, and suffers so little of it to pass directly to the opposite Extremity, as the blackest and most burnt Bodies.

Opacity again proceeds from the Variety of the Tracks of Light, caused by the Multiplicity of the elementary Laminæ of which Bodies are made. All these Laminæ, taken separately, are transparent; but when mixed, they so variously bend the Light, that they destroy the Direction and Sensation of it. The same happens to Oil and Water beaten together. It is likewise observed in Champaign Wine, when it is drawn from the Cellar, and the pressed Air it contains begins to feel the Heat and Communication of the external Air. It dilates and sustains the Liquor on its widening Globules; so that the Light, bending perpetually and in a Manner quite different in the Laminæ of the Wine, and in the Bubbles of the Air; it can no longer make itself sensible through the Liquor.

It is the Variety of the Inclinations of the Surfaces, together with the Diversity of the Refractions, which cause an Opacity in dry Paper, and in unpolished Glass. The small Intervals, which divide the Fibres of the Paper, are filled with Air: The Furrows, which have been drawn on the Glass, either by rubbing it with Sand, or by grinding it, are so many hollow Places and Pits, which are filled with Air. The Light, which in passing from the Glass into the Air of these Furrows has been bent there, falls on the Borders of those hollow Places, whence it is reflected towards our Eyes: But then it shews us the Surface which reflects it truly, instead of making the Glass appear transparent, in shewing us what is beyond that Surface. If you fill the Hollows of the furrowed Glass, or the Pores of the Paper, with Oil or Water; the Light, in passing from the Laminæ of the Rays of Paper, or from those of the Glass, into the Water which fills the hollow Places, there inclines to the Perpendicular. It follows an almost uniform

uniform Way, both in these Laminæ, and in the Liquor: It is less turned out of its Way, than if it should find those Cavities full of Air: Consequently a greater Number of Rays of Light must reach our Eyes.

From all those Instances, you see, Sir, that there is not one Body but what is naturally transparent; and it ceases to appear so, only when the Light is diverted or altered, either in the Irregularity of its Pores, or the Variety of the Particles, especially of the Fluids, which bend it in a quite different Manner. And this is so very true, that if the most opaque Bodies, such as Wood or Marble, are reduced into very thin Laminæ; then the Light, having not as yet lost its first Direction, yields therein a small Degree of Transparency. This may be remarked in a very thin Ivory or Wooden Leaf of a Table-book, when applied to the Hole of a Window-shutter, through which alone the Light was admitted into a Room. It may be seen likewise in the Laminæ of *Isinglais* or *Talc*, in *Allum*, in *Alabaster*, and in many Stones, which, being in their Nature less mixed with different Principles than other Bodies, become tolerably transparent, when made thin, so as to become a Kind of Glasses to us; which was very much in use among the Ancients. Again, this may be agreeably remarked in that fine and delicate Prait of the Rose of one of the three Graces whom *Germain Pilor* has placed instead of the three Virtues, in the Chapel of *Orleans*, at the Celestine Monks of *Paris*, to support the Urn designed to receive the Heart of King *Henry II*. If the Spectator stands so as to have that fine Groupe between the Windows and his Eye; then the Marble is so artfully fashioned in the Drapery of one of the Figures, that it has the Transparency and Delicacy of Cloth.

After having, with a general View, considered the Impulse of the Sun on the Fluid of Light; the Communication which is made of it round about according to strait Lines; the Weakening and Diminution of that Impulse, when Light is reflected by the Occurrence of Bodies, and divided in Proportion to the Number of reflecting Surfaces; its various Bendings in transparent Mediums; and at last the vanishing of it in Bodies wherein it is diverted out of its direct Way, and which thereby become opaque; let us now trace it in the Eye. The

Eye is the Goal where it is appointed to resort; and for the Eye it was made.

The several Causes which may either mislead or weaken the Rays of Light, and hinder them from reaching our Eyes, are easily discerned: But is it possible to know what its Operations are when it comes thither?

As Light is designed to enlighten the Eye; the Structure of that noble Organ is intirely disposed according to the Nature of Light; and it is because this is bent several Ways, according to the Variety of the Mediums it passes through, that the Eye was divided into three Partitions, filled with three different Humours, and so disposed, as to unite at the Bottom of the Eye the Rays, which, without that Artifice, could never arrive thither in good Order. The Plan we have proposed to our selves obliges us to defer to another Time the geometrical Measures of all these Tracks: But it is an easy Matter, without this precise Exactness, to make you sensible of some Parts of the Wonders of Vision.

The Eye is a natural Telescope, of the Form of a Ball, somewhat length in the Fore-part, and which the Creator has suspended by several Muscles, to direct it according to our Necessities. These, as well as all other Muscles, shorten as they widen, and lengthen when they contract. One is designed to raise the Eye: A second to lower it: Two others are appointed to bring it by Turns towards the Nose and the Temple: A fifth, which slides within a cartilaginous Ring, like a Cord over a Pulley, and is fastened to the Globe of the Eye in two Points, makes it roll about at Pleasure. A sixth lies under the Eye, and is designed with the utmost Gracelues to temper and restrain within proper Bounds the Action of the rest, which might otherwise be excessive and shocking. In short, there are a Multitude of different Pieces of Mechanism, which artfully assist each other, to make the Eye advance forward, retire, and move every Way; so that a single Eye is to us as useful as a thousand, by the surprising Variety of its Situations.

But the Action of a vast Number of different Springs is necessary to open or shut the Eye, to make it advance or draw back, to widen or contract its Orbit; in short, to govern it according to the Exigency of Occurrences. Is it Man that governs the Motions of it? Is it the Eye itself that

that turns seasonably and significantly ? Or is it God, who constantly and regularly performs the whole, according to certain fixed Laws, by which he has proportioned and submitted the Action of the Organs to our Desires ? Man knows neither the Organs nor their Functions ; and when by his reiterated Searches he comes to perceive the Effects thereof, or becomes able to distinguish them at least by their Names, it is always without understanding the Structure or Action of them. How then can he ascribe to himself the Government of his Eyes ? We are desirous to see : This is all the Share we are allowed to have in the Operation of our Eyes ; and we are free from the Management and Care of all the rest. Neither is it the Eye, which is endowed with the necessary Intelligence, to level itself towards the Objects, in the Manner which is the quickest, and yet the properest to make it receive just and faithful Impressions thereof. It is then God alone who has ruled, and who regulates the various Motions of our Eyes by our Necessities ; as it is he alone, who knows the Workmanship of them. Thus he operates, as in the Eye, so in all the other Organs of Sensation, a thousand different Ways, which Man receives the Benefit of, without ever being able to understand the Execution of them : And yet Man sometimes asks, where is God, and why he keeps at so great a Distance from him ?

The Hand which has so well placed the Eye, and made its Spring dependent on our very first Orders ; nay, often on our very Wants, without waiting for our Commands, and especially without perplexing our Understanding ; that Hand, I say, commands our Admiration still more, in the Fitnes and mutual Correspondence of the Pieces of which this Spying-glass is inwardly composed. We have as yet seen only the Carriage and Supports of it.

In order to give you an Idea of what is done at the Bottom of the Eye, without making the Anatomy of it, which I am for the present to avoid ; let us frame a rough Imitation of an Eye. Close the Window-shutters of a Room, and fit a Tube of Paste-board of a Foot long to a Hole that looks towards some public Square. The Pipe must be four or five Inches in Diameter, and closed next the Square with a convex Glass of five or six Inches Focus, that is, which unites the Rays at the Distance of five or

six Inches, and the Edges of which you must have covered with a small Circle of Paste-board, to hinder a too great Quantity of Light from entering. You are to introduce into this first Pipe, a second, covered with a fine Vellum, or a Piece of Ox-gut or of Bladder, tied on the End which goes into the first Pipe. If in the Middle of the publick Place, into which your Window looks, there stands a Figure on Horseback, or a Pyramid; let us chuse out three Points of the Pyramid, one in the Midd'e, one at Top, and the third below, in order to judge, from these three, of all the other Points which likewise reflect the Light. The Light from all Sides, or from all Parts of the Atmosphere, falls upon these three Points: It is of course thence reflected every Way. For you know that the Reflexion is equal to the Incidence; therefore a Bundle of Rays proceeds from the Middle of the Pyramid, and falls on the lenticular Glass fastened to the Window-shutter. What falls on the Membrane and beyond it does not concern us. Of all the Rays which fall on all the Points of the Glass, that, which falls directly on the Middle, goes through the Glass and the Tube without any Infexion: This then goes exactly to the Middle of the Vellum. Those of the Bundle of Rays, which are somewhat oblique with regard to the latter, meeting a Surface of the Glass already inclined a small Matter, bend there and incline a little to the Perpendicular. By this Means, they draw nearer that of the Middle; and meet on the Vellum at the same Point. Those, which fall farther towards the Edges of the Glass, are more oblique, and are received on a more inclined Surface. There they will bend in Proportion, and that Track, being more considerable, again brings them upon the Vellum, at the self-same Middle-point on which the perpendicular Ray fell. All these Rays gathered in a single Point, strongly paint in the Middle of the Vellum the Middle of the Pyramid. The Bundle of Rays, which from a Point arrives in widening on the Glass in the Form of a Sugar-loaf, may be called a Cone of Rays; and on the contrary, the Bundle of Rays, which from the Glass where they have been bent, go and gather in a Point on the Vellum, we will call a Pencil of Rays; because a single one would produce

produce on the Vellum too weak an Effect; whereas all these Rays gathered from one Point of the Object on one Point of the Vellum, there very strongly mark out one of the Points of the Image to be formed thereon.

From the Point that terminates the Top of the Pyramid, imagine a like Cone of Rays falling on the Glass: The several Parts of that Cone bent in Proportion to their Obliquity, will all meet together in a Pencil, the Extremity of which shall necessarily fall on the lowermost Part of the Vellum. On the contrary, there ascends, from the Foot of the Pyramid on the Glass, a Cone of Light, which shall gather into a Pencil-point towards the uppermost Part of the Vellum; and the same will happen to all the Points of the Pyramid in Proportion, and in moving the sliding Pipe backwards and forwards, you will at last bring the Vellum to the focal Point, or to the exact Medium where the Union of the Bundles of Rays, proceeding from each individual Point of the Figure, and gathering into so many Pencils, shall be depicted in order. From all these Pencils, there result a Multitude of small sharp Points, all coloured and exact, which being proportionably ranged among themselves, as those of the Pyramid are enlarged, present you with a perfect Picture of it on the Vellum, the Faithfulness of which far excels that of the Pieces of our greatest Painters. But as the Rays, that come from below, gather at the Top of the Vellum, and those, which proceed from the Right of the Obelisk, gather at the Left of the same Vellum, and so of the rest, the Image is inverted; so that the Pedestal is above, and the Cross below.

In thus shewing you what passes in that artificial Machine, I have, my dear Chevalier, revealed to you what passes in our Eyes. It is the same as to the Order and Operation. The Membrane of Paste-board designed to remove the Rays, which might come to disorder the Image, by their excessive Multitude, and by the Inexactness of their Union, represents the Iris or coloured Circle, which is on the Fore-part of the Eye; with this Difference, that the Paste-board always presents the same Aperture to the Rays; whereas the Iris of the Eye, by the playing of its minute Muscles, in proper

Time dilates the Aperture, which we call the Eye-ball, when we stand in need of a stronger Light ; and soon contracts it, when an Excess of Light might either confound the Image, or fatigue the Organ. Pass successively from a dark Place into broad Day-light, and from thence into the Dark, with a Looking glass in your Hand ; you will see your Eye-ball widening in Proportion as you enter into the Shade, and then contract in Proportion as the Light shall be more or less glaring.

The Manner, in which the Rays are bent in the convex Glass, and in the Air which follows it to the Vellum, is an Imitation of the Path of the Rays through the Humours of our Eyes : And as the Extremities of the Pencils form a clear and distinct, but at the same Time an inverted Image on the Vellum, *B A*, the same Pencils trace out, on the Bottom of our Eye, a small and very exact, but inverted Image of Objects, *C B A*. If after the Experiment of the Glass and Tubes, of which I have just shewn the Use, you should still doubt of the Inversion of the Image in your Eye, you might convince yourself of it, by placing at the Hole of a Window-shutter, which looks towards the public Place, the Eye of a Sheep, or of an Ox fresh killed. After having curiously taken off the thick Covers which surround the Bottom of the Eye, even to the transparent Pellicle which incloses the last Humour, you must apply an oiled Paper to it. Then the Obelisk which stands in the Middle of the public Place, the Houses and Inhabitants, will be represented most clearly, and in a wonderful Fore-shortening, on the oiled Paper : But all the Images will be inverted.

I must confine myself at present to this rough but true Idea of the Functions of the Eye, which well deserve that one Day or other we should make them a separate Study. We are now able to judge of the other Wonders of the Use of the Eye and of the Light. But, to judge of them the better, let us choose some eminent Place, where our Eyes may perform their Functions without any Obstacle, and where we may be sensible how precious they are, from the very Beauty of the Prospect itself. We may place ourselves either on the Flat of the Royal Observatory, or rather on one of the Towers of

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the Cathedral Church of *Paris*. So soon as I approach the Gallery which is at the Top, one Half of the Horizon, of near or perhaps more than six square Leagues, is represented in Miniature on the Bottom of my Eyes, with such Strokes as represent there the Mountains, the Royal Palaces with their Avenues, the Steeples of the Plain, and all the Buildings of an immense City. After having for a Moment indulged my Surprize at this ravishing new Scene, a Croud of Reflections occur to me upon every Thing I see.

My first Astonishment is to perceive so much Order in that magnificent Picture which covers the Bottom of my Eye, while an unutterable Confusion reigns at the Entrance of the Eye ball. From one single Point of the first Object, I perceive, for Instance, the Top of the Steeple of *Sainte Chapelle*; there comes on my Eye a Bundle of Rays, which, in widening a little, cover the whole Aperture of the Eye-ball. The Point of the Cross immediately following, sends thither another Pyramid, which fills a like Space, and all the Rays of which cross every one of the foregoing. If there are a thousand Points in the Cross, which render it visible to me by a thousand the like Cones; there will be ten millions of Cones, or radiating Pyramids, which will come from the whole Mass of the Steeple, and every one of which shall (taken single) make as many different Strokes on my Eye-ball, as there are Points contained in it. These Lines, crossing each other, overpower my Reason, by a Croud in which it loses itself, and where it meets with nothing but Confusion. What will it be then when from all the Buildings of the Town, and from all the remote Objects of the Plain, the like Quantities of Rays shall all meet at the same Entrance? The Iris, which secures the Entrance of the Eye, keeps off what is excessive, and admits only what is necessary: But that very Necessary is an Infinitude of Lines, united in the narrow Compass of the Eye-ball; and yet none of them shall go astray, but all follow their appointed Direction without any Mistake. All shall orderly, and in small Collections, go and lodge themselves in different Quarters: All those that come from the same Point, both

The Multitude
of Rays for one
single Eye.

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both from the Edges and from the whole Surface of the Eye-ball, again proceed and unite in a single Point of the Retina, which covers the Bottom of the Eye; that being the Place of Resort appointed for them. They are never confounded: They find their Way in spite of their Multitude, and gather at such Points as keep among themselves, and in Miniature, the very same Order which was observed among those Points of the Object from whence they came.

2. Here is still far greater Matter of Admiration. These Objects before me are not designed for me alone. I was surprized at the innumerable Quantity of Rays they send forth, on a Space so little as is the Breadth of my Eye-ball. They then send out as many on all the like Spaces of the Mass of Air which incompasses them. For that Reason it is, that wherever I go, new Rays always replace the preceding, and not only the People, whom Curiosity has drawn to that Tower as well as me, but also millions of Spectators, were they dispersed on the neighbouring Towers and Eminences, might see the same Objects as well as I. All the Rays, which would then serve them, are really in Action, and want nothing but Eyes to work upon.

3. Among all these innumerable Rays, which from all Sides arrive at every Eye, those which present themselves too obliquely, are reflected from, instead of being admitted into the Organ. These would infeeble, or even confound the Image of what is before us. But we shall make them of Use whenever we please, and we no sooner shall turn our Eye that Way, but they will be admitted therein. They then come from all Sides; they are always ready for our Service. But the great infallible Oeconomist has established Laws, which stop Part of them at their Entrance, that the rest may be more useful and efficacious.

4. All the efficacious Rays are not Efficacious and however the only ones admitted into the ineflicacious Eye. There are near these an infinite Number of others, whose Operations are more concealed, and which are overwhelmed by the Vigour of the first, but which are always ready to do the same Office in due Time. I, for Instance, make a Pin-

Pin-hole in a Sheet of Paper, and when I look through this Aperture, much narrower than that of my Eye, I will perceive the Houses of *Paris*: But the Prospect of them is much more contracted, and Objects appear much smaller. The Rays, which formed the first Image, shewed me larger only by Refractions, the Measure of which depended on their greater Obliquity. Those, which form this new and smaller Image, then suffer smaller Refractions: They consequently have less Obliquity, and are indeed other Rays. Therefore, wherever we carry our Steps and Sight, we find a new Light, and descry the Presence of an infinite Wisdom, which for our Sake sets innumerable Springs in Motion, and is pleased to make this Light be a beneficial Guide; even at the Time when it is dispensed to us in the smallest Quantity.

5. And indeed that Portion of Light, which from the Sun descends upon the Earth, is from the Surface of our Abode reflected to the Upper-parts of the Atmosphere. These Upper-parts, or that Mass of Air and rarefied Waters, is clear enough to admit the immediate Impression of the celestial Light, and at the same Time presents a sufficient Number of small Surfaces to the Light reflected from the Earth, to bend it towards the Earth again. It falls again and again on Objects; dashes from one to another, and is divided every Way from each individual Point. Thus a single Point first reflects a stronger Light; then one less strong; then a middling Light; and then a Light something weaker. All the Returns of these reflected Rays are as much varied as are the Incidences. The Eye, by this Means, receives from all Sides, and from the same Objects, Rays of several Degrees and Strength, and of various Obliquity, which produce a Variety no less infinite in the Effects.

6. But if we compare that Light, which enlightens our terrestrial Globe, with that which fills the whole Sphere of the Sun, and of the Planets known to us; what we just now admitted with Amazement dwindles even to nothing. Of all the vast Abyss of Light which the Sun presses on all Sides, and which he makes to radiate, even to the very Stars, we only share that faint Light which

which is reflected from the Planets towards us, together with the more abundant Portion of it, which falls immediately on the Earth. But if the Earth be no more than a Point in that Sphere, what must that Light be which falls thereon? What must that Portion of Light be, which gives Life to all its Inhabitants; which unveils so many Objects to them; which has so much Force, Activity, Suppleness, and Variety in its Effects; which, in short, is unfathomable to our Understandings, through the Multiplicity of its Operations? To speak the Truth sincerely; if the Earth be but a Point, all our terrestrial Light is no more than a single Line deduced from the universal Light.

7. And this perhaps would be the properest Place to make great Calculations, to find out vast amazing Sums, by multiplying the Cones of Light by the Points of the Objects; and again, by multiplying these Products by as many Breadths of an Eye-ball as the Atmosphere can contain; and finally, in multiplying this last Product, by as many like Atmospheres, as there may be contained in the Space of the hundred millions and more of cubic Leagues enlightened by the Sun: But instead of giving you whole Pages of Figures; let us rest satisfied with the Calculations of one of the greatest Admirers of the Works of God. * *How gracious are thy Wonders unto me, and how great is the Sum of them! If I would count them, they are more in Number than the Sand of the Sea-shore: How much soever I consider them; how earnestly soever I endeavour to gain the End, or comprehend the Greatness of thy Works and thy Perfections; still am I with thee. Whatever I see, like thee, is inexhaustible; and after all my Calculations, I am just where I was.*

Though it may be a Means of mending our Hearts now and then to presume to get a Glimpse of the Infinite; because we are never more sensible how far this adorable Being carries his Kindness towards us, than when we are most convinced of our own extreme Littleness: Yet it is of very small Use to consume our Time in Calculations, which distract our Heads, and in Arguments on Infinitude, which will always be very much below the Thoughts of the Creator. It is undoubtedly much

* Psal. cxxxix. 17, 18, &c. according to the Hebrew.

much better, generally to employ our Minds on what he places within our Reach, on what, in his Works, is most proper to affect us. It is then enough for us, at a Distance, and as it were through a Veil, to have viewed the Sources of the Light; to have traced it through its Paths, and to know the all-wise Laws, which insure to every Eye that Portion of Light, which is necessary to it. Now, let us behold the Wonders of that Picture, which the Rays delineate at the Bottom of the Eye; since it is that Picture, which becomes our proper Light, our Guide, and our Flambeau.

8. What surprises me first herein, is a perfect Distinction and Clearness, together with the utmost Littleness. We sometimes are amazed, on seeing a Portrait, very like, inclosed within the Bezel of a Ring. But here is one Half of the Horizon of *Paris*, that is a Space of above six square Leagues, faithfully represented within the Compass of not quite half an Inch. Here the Calculation is very easy; six Leagues, at the Rate of two thousand Fathoms for each League, as they reckon them at *Paris*, make twelve thousand Fathoms; which being multiplied by themselves, to make the Area of that Surface, will amount to one hundred and forty-four millions of Fathoms. I would fain know, what Space or Room the Picture of one of the greatest Objects I see on the Plain, can fill in my Eye, or nearly so. But as the Objects, which are very near me, fill a very great Space in my Eye, because they are more considerable with regard to me; and the most remote take up therein but a very narrow Room, because they must affect me less; let us chuse an Object but at a middle Distance, that we may obtain a more exact Degree of Proportion. The largest Building, which offers at a middle Distance in this vast Prospect, is the Gallery of the *Louvre*. It is not quite one hundred and fifty Fathoms long: Let us join it to the Pavilion of the *Tuileries* on one Hand, and to the *Old Louvre* on the other, which, together, let us suppose, make two hundred Fathoms: The Height quite to the Top is hardly more than 48 Feet or six Fathoms. The vertical Section or the Surface of it will then be 200 Fathoms by eight; that is, 1600 square Fathoms; which makes the ninety thousand

sandth Part of 144 Millions. Now there is the same Proportion between the Space which the Image of the Gallery of the *Louvre* fills in my Eye, and the Image of the whole Plain, as between the Gallery itself and the Plain ; consequently, this magnificent Gallery, with its fifty large Windows, and those of the *Louvre*, which I perceive distinctly, fill in my Eye no more than the ninety thousandth Part of half an Inch. How wonderful a Picture is this ! How great must be the Hand which drew it !

9. I perceive on the Plain a Coach, which insensibly removes from the Village it left, and by little and little goes into the Avenues of *Paris*. If I have a Mind to measure in the ocular Picture of the Plain the Space, which corresponds to the Dimensions of one League, which I saw the Coach make ; a League of above two thousand Fathoms shall not take up at the Bottom of my Eye near the Space of one single Line. What Space does then the Coach and Horses fill up in my Eye ? And if I cannot judge of their Motion but by the successive Alterations of Place made within my Eyes, of the small Image which represents their Feet ; this Image must not only have moved on five or six hundred different Points ; but also have fetched five or six thousand proportional Places within the Length of that Line. The little Horses, which the Light has painted at the Bottom of my Eye, continually change their Place there, and after a Course of Half or three Quarters of an Hour, they at last have finished the crossing over a twelfth Part of an Inch.

10. This wonderful Picture, thus formed at the Bottom of the Eye, is the Effect of the three Humours, which divide it. If the Bundles of Rays, which come and successively bend therein, should be gathered into Pencils there, before they touch the Bottom of the Eye ; or should they touch it before all their Strokes were gathered into a Point ; the Organ would indeed be shaken ; we should have the Perception of the Presence of the Light : But the Image being not formed by an Order of Points, which should imitate the Order of those of the Object, from which the Bundles of Rays came, the Vision would be confused.

Let

Let us not here overlook the Use, which God makes of those very Rays which most strike upon our Organ, and arrive thither in the greatest Disorder. Nothing makes a greater Impression on the Eye, than those long Strokes so uneven and so bright, or the Irradiations, which attend the Image of luminous Bodies. Whence can those Strokes proceed? How do they act? What are they designed for? God has placed at the Extremity of both the Eye-lids, a Border perfectly round, always moistened with an Oil, which issues from it through small Orifices, and makes it at all Times of the clearest Smoothness and Gloss. By that Means the Eye-lid slides over the Eye, without any Roughtess, and from Time to Time brushes it, to clean it of the very minutest Dirt or Dust, which the Hair of the Eye-brows or of the Eye-lids had not been able to stop perhaps or keep off. But that Border or String has still another very different Use: It is a true Looking-glass, rounded and prepared to reflect on all Sides, by that Roundness, the Light that falls thereon. The Light, which luminous Bodies send thither, is always more active, and that Part of it, which enters the Eye-ball, will always make a powerful Impression there. But there is but a very small Number of Rays reflected from the Border of the upper Eye-lid, towards the lower Part of the Eye-ball, that can enter it, as there is but a very little Quantity of Rays, reflected from the Border of the under Eye-lid towards the higher Part of the Eye-ball, that can be admitted therein. These Strokes, which, as you see, enter the Eye but obliquely, can never regularly pass through all the three Humours, nor bend in order to gather there, and consequently form neither Pencils nor Images: But they strongly strike on the Organ, by the Image which is at the Bottom of the Eye; and as these Strokes proceed from a Light, which passes between the Hairs of the Eye-lids, they necessarily are confused and broken into long Streaks, the Breadth of which resembles the uneven Separations of the Hairs. Thence proceed the radiating Crowns, which incompas the Image of a Candle seen at a great Distance, and above all, the Image of the Stars and the Sun. Would you be certain of the Fact? Draw your

The radiating
Crowns of lu-
minous Bodies.

your Eye-lids very near one another, at the Sight of a luminous Body ; in uniting a very great Number of Hairs, to break the Light which arrives on the round Borders, you increase the Number of the large Strokes, so far as to confound and perplex the Image of the luminous Body. Have you a Mind to produce a quite contrary Effect in your Eye ? Take a Wheat-straw, the smallest Part of it especially, and nearest to the Ear ; put the End of it through a Paper, and look at the Sun through the small Hole of that Pipe ; the Rays which come through this narrow Channel do by no means fill the whole Compass of your Eye-ball ; and this shall render the Image of the Sun, or of any other Object, much smaller. But if the Rays of the Sun cannot this Way get at the Borders of the Iris, which regulates the Opening of the Eye-ball, much less will they reach the Borders of the Eye-lids, which are still more remote : But then, you will see radiating Crowns no more. Perhaps some few Rays, reflected from the Inside of the Straw, shall at most shew a few feeble Strokes here and there, and several varying Colours round the solar Image ; but the large Strokes will be intirely vanished, and a Star seen through a Pin-hole, or a long Pipe, is no more than a single Point without any Splendor or Beauty.

Let the Ungrateful and Senseless (for I shall make no Distinction between them) say after this, that he, who made the Stars, had then not Man in View. It is so very true, that he made the Stars for the Eye, and the Eye for the Stars ; that, in order to insure the Services of these remote Globes to Man, and to render the Impression of them lively and affecting to him, notwithstanding their extreme Remoteness ; he took the Caution to dispose round the Eye two cylindrical Looking glasses, which, without forming any Image, imbellish, strengthen, and set off, by a radiant Circle, the Image of the Star, or of the inflamed Body delineated in the Eye. You had hitherto looked upon the two Pads, which surround our Eye-lids, as two very indifferent or insignificant Things ; but the weakest Instruments become fruitful in great Effects in the Almighty's Hand. The Sun, with all its Fires, would not afford us the Splendor of the Day, were it not for the Bubbles and Spherulites of the Atmosphere.

Atmosphere. The Light, reflected from the whole Vault of the Atmosphere, would not render Objects visible to us, were it not for the Humours of our Eyes; and it is from the bare incircling of two small round and glazed Strings, that God produces the chief Brightness of all our serviceable Lights, the finest Strokes with which he crowns the Sun, and the whole Glory of the Heavens in general.

11. But we should still remain in Darkness, and in a real Chaos, notwithstanding the all-wise Proportions God has put between the Structure of the Light and that of our Eyes, in order to make us correspond in general with the Universe; did he not every Moment create in us a particular Kind of Sensation, which informs us constantly of the Presence of every Thing round us. The Light, the Eye, and our Sensations, do then proceed from the same bountiful Hand, and from the same benign Intentions. If other Animals have a Share in the same Advantages, as I believe I have demonstrated to you that they were provided with Senses capable of guiding them, purposely that they might free us of a great many Cares, and in a Word, that it is for us alone they live and see; the Succours, which enable our Domestics to serve us well, ought much rather to raise our Gratitude than our Jealousy. The great and important Truth, which presents itself here as a Result of so long a Series of Wonders, is that we incessantly experience in the Heavens, on the Earth, and within ourselves, the Action and Influence of an infinite Wisdom, whose Business it is to govern us, whose greatest Delight is to dwell amongst us.

The Light reflected from a Tree, and bent within my Eyes, may affect them, it is true: It delineates two Images in my Eyes, and I see but one Tree. It paints in my Eyes an inverted Image, and I see the Tree in a direct Situation and upright. It paints in my Eye a Tree, which does not fill by much the hundred thousandth Part of one Line, and the Tree I see is eighty Feet high. I myself am not six Feet high, and two Feet broad, and have the most real Sensation, not only of a very large Tree, but of the Plain of St. Denis, and of the Distance which is between the Earth and the Sun.

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Sure this is incomprehensible: But it is only the more evident, that this is the wonderful Work, not indeed of the Light, which can only agitate the Bottom of my Eye; nor of Nature, which is an Idol, a mere ideal Power void of Reality; but of God alone, who intimately operates within me. Therefore, the Sight of a Tree and of the Sun, which God shews me, is as real and as immediate a Revelation, as that which led *Moses* towards the burning Bush. The only Difference, between both these Actions of God on *Moses* and me, is that the first is out of the common Order and Economy; whereas the other is occasioned by the Sequel and Connexion of those Laws which God has established for the Regulation both of Man and Nature.

12. The Habit of seeing so soon as we open our Eye-lids, makes us look upon that Operation as a Thing extremely plain and intelligible: However, I shall boldly assert, that the Mysteries of our holy Religion are not more above our Understandings, than the Manner in which we see, or than that inmost Sentiment which we experience, of the Disposition and Magnitude of the Things which are so remote from us. That my Eye, by the Help of an Image but fix Lines broad, or my Soul, with an Organ of half an Inch, should see eight or ten square Leagues, and discern the Beauty, the Form, the Situation, and Distances of a million of Objects dispersed all over this Plain, is a Mystery truly inaccessible to all our Reasonings. That Operation must either be corporeal or spiritual: But whatever it may be supposed to be, it will in both Cases be equally above our Reason. It is an unfathomable Abyss: But it is a Truth, and an undoubted Matter of Fact. What I can conceive of it (and that is a great deal for me) is, First, That God being alone able to work this Miracle within me, I continually experience the Effects of his Presence and Goodness. Secondly, That in Nature, as well as in Religion, he is pleased to grant me the Use and Communication of certain Blessings, and of certain Truths, without unveiling to me as yet the Ground and Nature of what he vouchsafes to inform me of; and in short, that to dispute proved and attested Truths, by alledging that one does not conceive them, is as little reasonable;

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as if I should say, I actually do not see *Paris*, nor its Churches; because I do not conceive how, being so little, I could have the Perception of so vast an Extent. Unbelievers build on the Authority of this Principle of modern Philosophy, *viz.* not to admit of any Thing, but what we clearly and evidently know. Let them say then, when they open their Eyes to the Light; *I see nothing, for I conceive not how any one can see.*

O F C O L O U R S.

D I A L O G U E IX.

INSTEAD of a Field imbellished with all the greatest Beauties which the Spring and the Art of Man may convey and gather there; let us conceive this all over covered with Snow. The Light of the Sun, which begins to ascend our Horizon, is strongly reflected by that universal Whiteness which overspreads it. It gives a greater Brightness to the Day. Our Eyes may freely expatiate over the whole Plain, its Surface being intirely open to us: Every Thing is enlightened and visible, yet confused; and this Confusion of the Objects does not properly proceed from the Thickness of the Snow which covers them: For the River is still sensibly lower than the Meadow, and the Meadow lower than the arable Grounds. A Tree or a House still preserves a Form, which helps us to distinguish them tolerably well. We must be at the Trouble to guess, however; and the Uniformity of the Whiteness, notwithstanding its Splendor, hinders us from distinguishing the Rocks from the Habitations of Men, the Trees from the Hills which bear them, the tilled from the untilled Lands.

We

We then see all, but can distinguish nothing. Such would have been the Aspect of Nature, but God allowed us without the Distinction of Colours. The Distinction of the Objects.

We every Day admire that noble Art, which, by lightly spreading a few Colours on a Cloth, makes us see thereon Objects which do not exist. It deceives us by shewing us a mere Outside and Drapery: But if this Distinction of Colours, skilfully managed, is alone sufficient to make Realities appear to our Eyes, where there are none; it very plainly shews the bountiful Intention of him who has painted and cloathed whatever is round us. Each individual Piece was by him rendered distinguishable. Each Kind wears its peculiar Livery. Whatever is for our Use has a distinguishing Mark which characterizes it. We need be at no Trouble, when we want to discover the Things we look for. The Colours point them out to us.

To what Delays and Perplexity should we have been reduced, had we been obliged every Minute to distinguish one Thing from another by Reasonings? Our whole Life must then have been employed rather in Study than in Action, and we must have remained in that eternal Uncertainty, in which Naturalists sometimes are, with the most magnificent Hypotheses; or as Chemists, after a thousand Dissolutions.

God's Intention was not to busy Mankind about empty Speculations. And it is plain, that he concealed from us the Ground and Principles of Beings, in order to recall us effectually to the Necessaries of Life, and the Practice of Virtue. The Earth was not made to lodge Philosophers apart, and solitary Dreamers, but to be covered with a Society of Brethren, bound to each other by Wants and reciprocal Duties. For this Purpose it was, that God, instead of the long and tiresome Method of Inquiries and Researches into the Nature of Individuals, was pleased to grant Mankind, and even the Animals that attend them, the commodious, easy, and expeditious Way of distinguishing Objects by their Colour. Man opens his Eyes in the Morning, and behold, all his Researches are made. His Work, his Tools, his Food, and whatever concerns him, clearly offer themselves

selves to him : He is at no Manner of Loss to distinguish Things. The Colour is the Direction which guides his Hand, and infallibly leads it whither it ought to go.

The Design of making us quickly distinguish Objects at Sight, is not the only Thing that gave Birth to Colours. In this, as well as in every Thing else, God has had Respect to both our Pleasures and our Wants. To what other Purpose than that of placing us in a delightful Abode, can he have adorned every Part of it with Pictures so striking and so diversified ? The Heaven, and whatever is seen at a Distance, were drawn at full Length. Splendor, Sublimity, and Loftiness of Style, are the Character of them : Lightness, Delicacy, and all the Beauties of Miniature, are found again in Objects, designed to be seen nearer, such as Leaves, Birds, and Flowers. And lest the Uniformity of Colours should become in a Manner tedious ; the Earth changes its Garment and Attire every Season. The Winter, indeed, robs it of great Part of its Beauties ; but it brings on a Repose, which is of Use to the Earth, and of still greater Use to him who cultivates it. Why should the Earth, while Man is obliged to hide and shelter himself, adorn herself, not to be seen by her Master ?

These Colours, which make so beautiful an Effect in Nature, are no less an Ornament to Society and Mankind.

They facilitate all their Operations, as they do those of a great Army. They every where assist Subordination, by distinguishing Conditions. What a Decency and Gracefulness do they give to our Clothes and Furniture ? For ever employing the Pencil, the Graver, the Shuttle, and the Needle : But after all these have had their first Preparation under the Hand of the Artist, they still are improved, by being placed beautifully, and matched with Judgment and Taste. A Merit they generally owe to the Industry of the fair Sex.

But of all the Services which Colours are of to us, the most engaging is their so well answering all our Intentions, and so readily agreeing with every Situation. The most common Colours serve for ordinary Uses, and for Things of little Concern. The most lively and

and brilliant are reserved for greater Occasions. They inliven our Feasts, and by their Splendor convey every where a secret Joy and Satisfaction, almost inseparable from them. Are we in Affliction? Other Colours then take Place. They surround us with Mourning, and it is a Sort of Comfort to us, to see whatever approaches us, as it were, concerned for our Troubles, and sharing our Affliction.

These Colours, designed to vary so usefully the Scene of the World, greatly deserve our Attention to them a Moment, in the Enumeration of the Uses for which they are fit; which may convince us they have a Rank among the noblest Gifts of our Creator. But can we be certain what they are in themselves? Are they inherent in the Objects? Do they exist in the Light? Do they reside only within us?

It is with Colours as with all our other Sensations: They are partly within, and partly without us. What affects our Soul

The Nature of Colours.

immediately, is properly no where but within ourselves: But what we experience is relative to what passes within us. I feel a violent Pain when the Fire burns, or a Needle pierces my Hand. But the Smart I feel is neither in the Fire, nor in the Needle. Flowers may indeed exhale some Spirits; but the Smelling is no where but in me. Musical Instruments, when struck, do really shake the Air: But the Sound and Harmony affect the Soul alone.

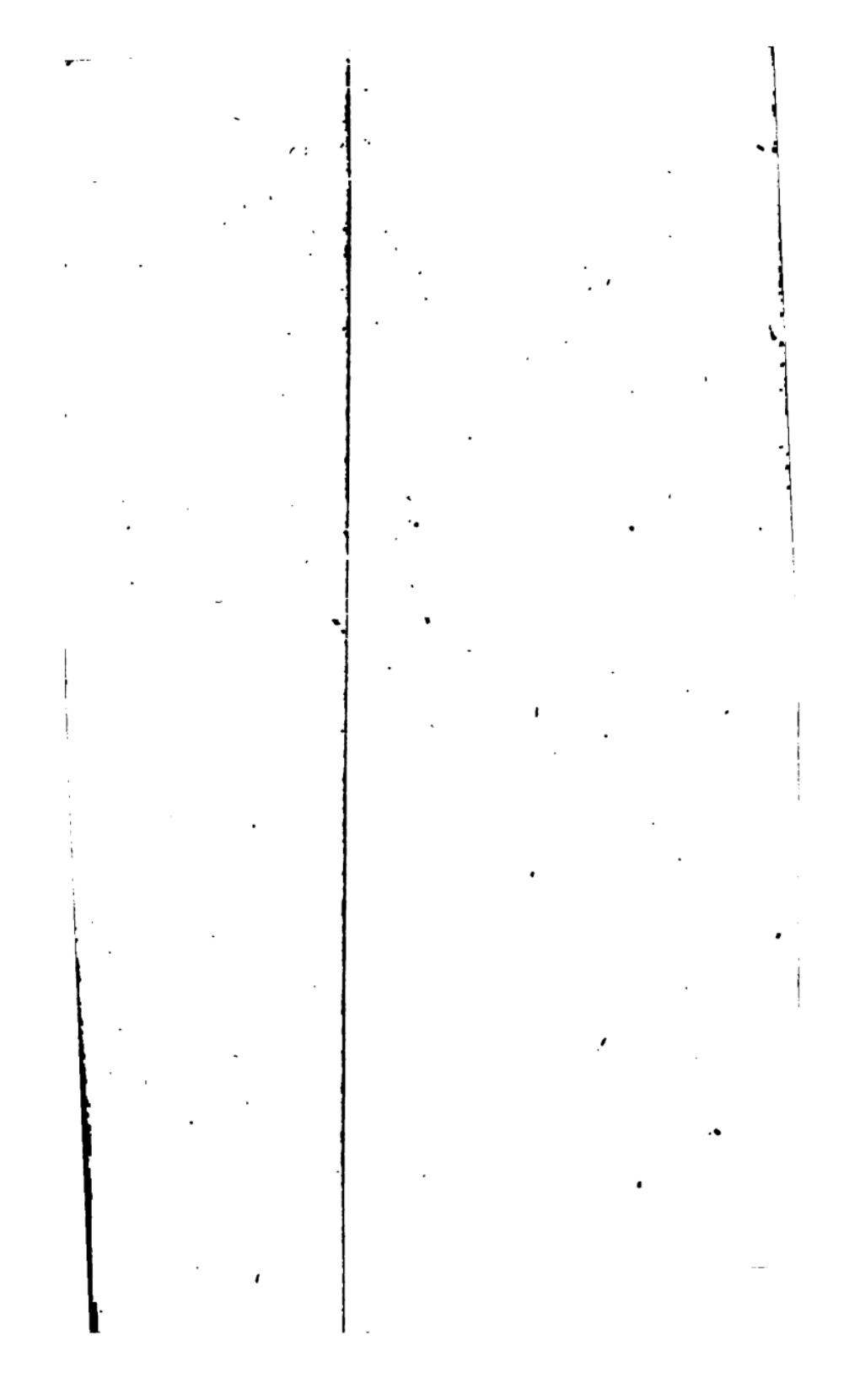
Thus the Red which exhilarates me, and the Black which makes me sad, are so many Perceptions of the Soul, and so are all other Colours. They are so many lively Notifications that we receive of what passes about us. These Sentiments are so truly our own, they are so really within, not without us, that by the Effect of an Order established to keep our Souls always busy, we in our Sleep still experience the same Sensations, the same Smells, the same Savours and Colours, though there are no longer any external Objects to excite them. In vain should we say, that these are only the Remains of the Sensations we have experienced, revived again within us; nothing but a remaining Emotion, which blends itself with several others within the Brain, and is fol-

lowed by the Sensation annexed to it. I grant it. But the Reality of that Sensation is the same as when we are awake. We then see the same Colours, the same Objects, and at the same Distances. None but an infinitely powerful Being, none but a Being intimately present every where, can thus cause and perpetually create in us all these so exquisitely regular Sensations, which unite us to every Thing about us. And as those Motions, which displace and transport Bodies, are the Laws by which God acts upon Bodies, so that the several Degrees of these Motions are still no other than the Actions of God diversified; so likewise the Sensations, which affect our Souls, are those Laws by which God acts upon our Soul; and all the Varieties of Savours, Smells, Sounds, Colours, in short, all our Sensations, are nothing but God's Method of acting on us, diversified according to our Wants.

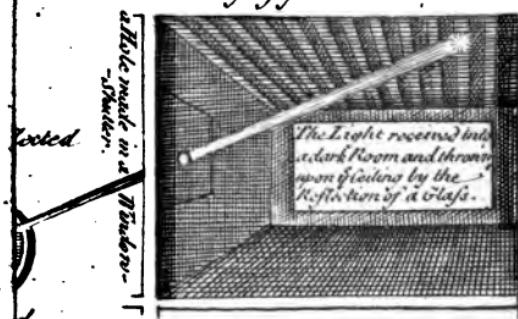
Let us not glance upon this Truth too slightly. Every Thing contributes to convince us of it. The Bodies, which surround us, do not come and graft themselves upon our Mind; nor does our Soul get out to diffuse itself outwardly, and to become acquainted with what passes there. The Light, which extends from the Objects to us, is nothing but a Mass of Corpuscles, which can at most only strike our Eyes variously; and this or that Impression is not of itself more fit to cause the Sensation of Yellow, than that of Purple. I perceive therein an Oeconomy intirely free, and that these Perceptions, so exquisitely regular, are the Work of an almighty Being, who has established and makes us sensible of them in an uniform Manner, to acquaint us of whatever may be of Concern to us. How affecting this Truth is! And how fit too to maintain within us an awful Sense of the Presence of Him, who communicates himself to us by intimate Influences, by Advices, and by perpetual Favours! But this Revelator, which God makes perpetually to us of the whole Oeconomy of Nature by the Ministry of our Senses, is become so familiar to us, that we forget the Author of it. And we complain of either his Unconcern or his Remoteness from us, while we both receive from, and have in him our Sensations, Motions, and Being *.

But

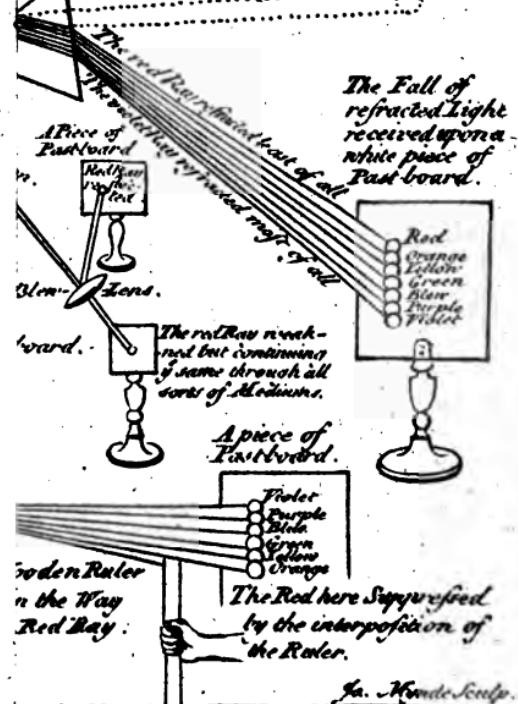
* In him we live, and move, and have our Being. ACTS xvii. 28.



An Image of a Hole in the Shutter.



The direct Passage of a Light



But if the Colours, which touch us immediately, are nothing but the Action of God, diversified in us by the Presence of the Bodies round us; we may now inquire, what are in Nature the Accidents, Strokes, and Motions, to which God has annexed those Sensations by which he affects our Souls. If what, by striking on our Eyes, ~~gives Occasion~~ to Sensation of the red Colour, is constant, and something different from what produces in us the Impression of Green; what should hinder us to call that a red Ray; or a red Body, which is the Occasion of our seeing that Colour, or to call that a yellow Ray, or a yellow Body, which excites in us the Sensation of Yellow; since all Ambiguity was removed, by rightly distinguishing the Perception of sensible Colours, which is only within us, from the Strokes which proceed from external Objects, and which are properly corporeal Colours?

These are of two Kinds: Some are in the Rays of the Light themselves; The Colours others are in coloured Bodies. That there of Light, are in the Light Rays essentially red, others of another Colour peculiar to them, or in short, Rays differently framed, is what can no longer be doubted, after the Multitude of Experiments, which Sir Isaac Newton * made with all imaginable Success, for his own Information on that Point; let us satisfy ourselves with the plainest and most practicable of them. They make in a Window-shutter a small Aperture of an Inch in Diameter. When the Sun shines bright thereon, the Rays, received through the Hole into a Room made dark, paint the Image of the Sun, or of the round Aperture, on the Wall, or on a Cloth, or on a Screen set to receive them. If, close to the Aperture, you present to the Rays of the Sun the Side of a Prism, that is, of a triangular Glass well chosen, ground true, and smooth; the Figure, which the Rays then make upon the Cloth, is no longer round as before. It still remains of the same Breadth: But it becomes very long, is terminated by two strait Lines in its Length, and rounded only at either End. Towards one of the

* Consult Newton's *Optics*, *Gravesand's Institutio*, and the Experiments which are made at the *Abbe Nollet's*, *Quai Conti*.

Extremities of this Figure, you perceive the finest Red, then the Orange Colour, then the Yellow, and next the Green, the Blue, the Purple, and the Violet. These seven Colours are not exactly separated from one another; but you see, between every two of them, gentle Gradations, which partake of the neighbouring Colours, and have something of a Mixture or Confusion in them. After having attentively examined this extraordinary Figure; they found out that it was composed of Rays differently coloured, and which being in themselves of a different Nature, go through quite different Tracks in the Glass, and therefore are differently refracted or diverted, so as to fall on the Cloth at Points variously distant from that on which they all would have fallen, had they not been refracted in the Glass. A flat Glass is not fit to produce this Effect; because the Thickness of it, being equal every where and the same, the different Rays, which suffer different Refractions there, are in Proportion very differently bent in their coming out of the Glass into the Air, which brings them again to their first Progression; so that they seem not to have been bent. They remain so near each other, and so much blended, that one Colour does not overpower the other. But if the different Rays have the least Inclination in their own Nature to be bent or refracted differently from each other in the Glass, this Difference shall become sensible, if they fall obliquely on a Glass, the Thickness of which is continually increasing. For two Rays, which going into a flat Glass incline towards the Perpendicular, with a very slight Difference or Inequality, will come out of it quite close to each other, and without forming any sensible Angle: But if, in their entering the triangular Glass, they are bent with a Difference ever so little, that Ray, which falls a little lower in the Glass, having a greater Thickness to go through, increases its Divergency. When afterwards both these Rays shall come into the Air, their Separation, still inconsiderable, though very real, will become more sensible. At the Distance of some Feet more, the Sides of that Angle will have a still greater Divergency, and at twelve or fifteen Distance, two Rays, which in the Glass were divided but a single Point, will be separated by an Interval of half

an Inch. The Ray which is the least diverted from its first Direction, or least refracted, is the Red. That which recedes most therefrom, is the Violet: But then the Red is always at one End of the Spectrum or Figure: The Purple is at the other End: The rest of the Colours are between them in the above-mentioned Order. The red Ray is not single, any more than the Yellow or the others: But after a deeper Red, there comes a Red of another Degree. The same Tones, Diminutions, and Gradations are found in the other subsequent Colours. Every one of these Rays throws on the Cloth a round Figure, corresponding to the Aperture of the Window-shutter. And as these several round Figures are but little distant from each other, thence proceeds the Groupe of neighbouring Colours in that List of Figures that touch each other. Hence the Uniformity of the Breadth of the whole Figure: Hence the two strait Lines which terminate it, and which are nothing but the Extremities of all those round Figures delineated by all the different Rays: Hence, in short, the Roundness of the two Ends of the Figure, where the two Extremities of the two round Images, delineated by the Red and Purple, must necessarily be. All these Circles, delineated by so many differently coloured Rays, and from which a longish Figure rounded at both Ends does result, can never be better represented than by a Row of Gold, Silver, Copper, Brass, and other metal Coins ranged on a Table, and covering each other more than one Half. This Row of Counters is of several different Colours, bounded all along by two Lines apparently strait, and at last rounded at both Extremities.

If these several Rays, after having passed through one Prism, are received into a second, and then into a third, there they suffer great Refractions, and form an Image still longer, but never lose their Nature, and constantly keep the same Order among themselves. The Red is always first: Then follows the Orange colour. What was yellow in the first, still remains yellow in the third Prism. The Green never loses the Middle-place; in a Word, each Ray keeps its Colour invariable. To be the more certain of this; present a Wire, or a Slip of Paste-board, to the Point of the first Prism, where the Beginning of

the Light passes : If you do it on the Side where the red Ray is, that Colour disappears on the Cloth. Bring the Wire a little farther, the red Ray immediately shews itself again, and the Orange-colour vanishes. You thus make them successively vanish and return in the Figure or Spectrum at your Pleasure. It is not then the Mediums, through which the Rays pass, that give them different Colours : But the Mediums, and all Bodies in general, receive these Colours from the Rays themselves, every one of which is of a peculiar and invariable Nature. You may even make yourself still surer of it. Stop the Mass of Rays which cross your Chamber, by putting a Piece of black Paste-board with a small Hole into it in the Way : Through this Hole receive only the red Ray which you separated from the rest by Means of the Prism ; it shall mark out a small red Spot on the opposite Cloth. Make this single Ray pass through a second, a third, and a fourth Prism, or through a yellow or blue Glass, yet you will have only a red Spot. Likewise, if you receive a blue Ray, it will remain blue in all the Mediums into which you shall introduce it, and in all the Proofs which you shall be pleased to make of it.

The Rays have then in the corporeal Light, First, A Colour and a Constitution peculiar to every one of them. Secondly, They have each its different Degree of Refrangi-
bility, that is of Disposition to be refracted or bent. They have a third Property, *viz.* That the most easy to be bent in the Glass is likewise the easiest and soonest reflected, when it reaches the Surface of the Air on the other Side of the Glass. Those, which have the greatest Refractions, are the first reflected when the Obliquity of the Air, into which they tend through the Prism, becomes great. For this Reason, when they give the Prism a Mo-
tion, which increases the Obliquity of the Light, with re-
gard to the last Surface of the Glass, and consequently with regard to the Air which touches that Surface ; the Purple is the first Colour, to which the Air on the other Side the Prism refuses a Passage, and which being totally reflected in the Prism disappears in the long Figure pro-
jected on the opposite Cloth. If by inclining the Prism, you a small Matter increase the Obliquity of the Rays, then the Indigo-colour vanishes, then the Blue, and so

of the rest. The rest however is the last that leaves the Place.

But when those Rays, which we but now saw separately, by Means of the Prism, are united and concur; then it is that they produce a wonderful Appearance, far more surprizing than all we just observed. According to our Notions, they should be much altered by their Re-union; and make a dull muddy Colour; as happens to the Colours of Painters, when they are blended together on the Pallet. The Reverse of this happens to the united and concurring Rays of the Light. They then make the clearest and the most lovely White, which becomes imperfect only in Proportion as its Tracts are discomposed and not collected. After having, by Means of a round Magnifying-glass, called a *Lens*, united all the Rays that come from the Prism, and gathered them on a Piece of Paste-board, into a very small round Spot of the purest White; with a Ruler cover that Part of the *Lens* on which you observe the blue Rays to fall, and the little white Spot becomes yellowish, or of a dull and dirty White. Put the Ruler on the Part of the *Lens* where you see the red Rays enter; the Spot then begins to become bluish. From the Combination of the seven chief Colours, and of their several Degrees differently blended, the Grey, the Brown, the Olive, &c. the Slate-colour, and all the other subordinate Colours proceed. The Black is not in Nature: It is nothing: It is a Privation of a reflected Light; and the less Reflexion there is, the deeper is the Black. But we may much better conceive, how we are to judge of it, when after having seen the Rays themselves, we shall have dwelt a Moment on those Bodies which reflect them, and which we shall call coloured Bodies.

The Elements, of which the large and Coloured small Surfaces of Bodies are made, must dies. be conceived as Laminæ of an extreme Smallness, of a different Nature and Thicknes, and differently inclined to each other. The Rays of Light, being in their own Nature quite different among themselves, find not the same Relations and Dispositions in all those Laminæ on which they fall. One Lamina, that will receive and reflect the Yellow in its Pores, shall totally immerse the Green. Another will partly admit a Ray, and partly reflect

reflect it. A third, which in a certain Degree of Inclination wou'd have admitted and refracted the Purple, being differently placed and inclined, refuses all Manner of Passage to it, and reflects it intirely. At first Sight, it is plain that this may be diversified *in infinitum*. Here a single Instance may account for ten thousand. Woollen Stuff is made up, as it were, of an infinite Number of small Threads, themselves made up of other Threads still incomparably finer. By this Disposition it is capable of reflecting all the Rays of Light ; which gives it the white Colour. But the Dust insensibly sticks to it ; a Drop of Oil falls on one Place, some other Liquor is flung on another. Thus new Laminæ are conveyed into the Pores of the Wool, whence follow Reflexions of some certain Rays, which being alone in that Place, interrupt the Whiteness, and form a Spot, by the Interruption of the Uniformity of the rest of the Surface. You scower that Cloth : You cleanse it from that heterogeneous Laminæ, and give it its former Whiteness. If you dye that Cloth, what do you do to give it a new Colour ? The whole Art of the Dyer amounts to only replenishing the Pores of this Cloth with Particles separated from the Cochineal, the Grain of Scarlet, or any other Matter used for that Purpose. The Multitude of the new Laminæ which they throw into it, and which they know how to make to stick close thereto by Means of Allum, &c. is so great, that the whole Surface and Inside of the Stuff are impregnated with them. And all these Laminæ of an uniform Structure, being fit to admit within their Pores all Sorts of Rays, except, for Instance, the Red ones ; the Stuff in this Case shall reflect none but the Red ; and that in a certain Degree of Strength, or with a Mixture either of Purple or of other Tints. It will either be a Scarlet-red, a Crimson dyed in Grain, a Cherry-colour, a Rose-colour, a Flesh-colour, or any other reddish Colour whatever. It is true, there remain always in that Stuff some Laminæ fit to reflect green, blue, or other Rays : And this is so very certain, that if you offer to a scarlet Cloth, or lay on a blue Stuff, a yellow Glass, that is, one mixed with small Laminæ fit to admit every Way a great Number of yellow Rays, then either the blue or red Stuff shall contract a yellowish Colour ; whereas the same yellow Glass being applied to a yellow Stuff,

Stuff, shall much heighten its natural Colour. For a like Reason it is, that a Cray-fish, from the greenish Colour it had when alive, becomes red when boiled. The Fire, which penetrates the Cray-fish, carries off from the Pores of its Shell the Lamineæ of Oil, Salt, &c. that filled them, and brings forth Lamineæ fit to reflect the red Rays, and to absorb all other. The Stuffs, you call changeable Stuffs, are made up of a Warp of one Colour, and a Woof of another: Whence it happens that we see both Colours shine in it, either successively or together. The Neck of a Pigeon, a Pheasant, or any other Bird, is covered with Feathers, which have each a double Row of large Lamineæ, every one of which is made up of a double Row of other small and extremely thin Lamineæ. The large ones are of a clean Texture, and covered with an Oil which makes them shine: The other subordinate Lamineæ make several different Textures. The Elements of these different Orders being differently porous, and differently ranged, of course reflect or admit quite different Rays. The Bird cannot move his Head ever so little, without presenting to our Eyes sometimes small Surfaces, fit to reflect Rays of a certain Kind, and sometimes other Surfaces fit to reflect Rays of quite another Species.

We shall conclude these Remarks by the Black, which may serve to confirm every Thing we have said. A black Surface is nothing but a Heap of porous Elements, or Lamineæ pierced through in such a Manner that almost all the Rays are admitted and totally absorbed therein: So, that by reflecting scarce any of them, the Body becomes black, even so as to appear a Hole, or deep Hollow, rather than an Object. This we easily observe in those-coloured Bubbles, which Children make with Water and Soap. The Salt, Water, and Oil, which make the Sides of the Bubble, are heavy Matters, incessantly sinking down towards the lowermost Part; so that the Bubble grows extremely thick there, and as thin upwards. As the Elements, which compose the upper Part and Sides of the Bubble, become thin and tender, they reflect Colours-livelier, finer, and of a more pleasing Delicacy: But they become so very thin towards the upper Part of the Bubble, that they admit the Light intirely, and reflect not the least Ray; which ought to make that Place appear quite black.

and so, indeed, it does. There seems to be pretty large Holes at the Top of the Bubble; because the Sides, which are still real and intire in it, reflect no longer any Rays, are no more perceived, and the whole Bubble bursts the next Instant after.

Colours are then essentially different in us, in the Light, and in coloured Bodies. In us, they are so many intirely different Sensations, with which God intimitely affects us, in order to distinguish the Appearances under which he presents all the Parts of the Universe to us. In the Light, Colours are so many plain Strokes perfectly distinguishable from each other; but which, besides their primitive Variety, still form, by their several Mixtures, an infinite Combination of Changes and Gradations. Colours, in short, are very different in Bodies themselves; and besides the Variety of Appearances, there is an absolute Foundation in coloured Bodies, to affirm of one; that it is truly red; and of another, that it is blue or yellow; since the small Particles, which reflect one of these Colours, are, by the Inequality of their Structure, of their Density, Delicacy, Combination, and Inclination, very different from those Elements which compose a Surface of another Colour. The small imperceptible Particles of the Surfaces of all Bodies are so many Sieves, which, as it were, sift the Light. The Rays, which may be received and admitted through the Pores of one of those Sieves, may be rejected by another. The White is a very fine Sieve, that suffers nothing to pass through. The Black is the coarsest of all, which lets every Thing through. For this Reason it is, that a single Sheet of perfectly white Paper, covering the Hat of a Traveller, or the Cap of a Child that walks, saves him from excessive Heat, by reflecting it into the Air. For the same Reason it is, that black Stuffs, and all black Bodies, are sooner heated, and more easily burnt.

Here the whole Science of Physics, with all the Systems, presents itself to give us a clear Conception, by what Mechanism the Substance of Light performs all these Miracles. One Hypothesis pretends to account for them all, by making the Globules of Light of Particles of unequal Sizes; so that the biggest shall form the Red, and the smallest make the Purple: And in order to Support this Supposi-

Supposition, they have Recourse to the Violence of the Red, which fatigues the Eye, while the Violet affects it but very moderately. Another System pretends to extricate itself better, by giving the Globules of the Light, or their Particles, different Degrees of Swiftness. Another, afraid of altering by these Inequalities the Equilibrium essential to Fluids, will needs have Recourse to a Diversity of Figures in the Particles of Light, and in the Pores of the Surfaces struck by them. Many other Systems may be devised and thought of. It is fit we should listen to them all, and be bigotted to none; not only because there is no Explication, that can account for every Thing we see in Nature; but because we are not sure, that the Mechanism, which appears to us the most probable, is exactly what the Almighty made use of. But the Benefit we may reap from those little Systems invented by Men, is this; that though there were in Light no other than the Art we endeavour to conceive therein (and no doubt what we thus imagine is far inferior to Reality) yet does it always hold true, that there is in Light no Globule or Particle, but has received its proper Shape and Weight, its Degrees of Swiftnes, its Place, and appointed Course. Whatever System or Oeconomy we may be tempted to espouse, in the one as well as in the other, it is evident, from the Regularity of the Effects, that all these Particles of Light have received Orders peculiar to them, and which they most faithfully execute. They march together, but every one in its Rank. One never anticipates the Right of another. In some Cases, they are to enter Bodies without any Order or Distinction. In others the Precedency is fixed between them. When they go separately, in entering the Red always goes first, and the Orange and other Colours enter in their Turn, but Side-ways, and with Deviation, as it were, or a Glance. The Purple always take the last Rank of all. The Order of their Return is no less regular. When these Colours fall on a Surface which can admit them all, and at the same Time the Obliquity under which they fall begins to be great; the Purple rebounds the first, and no longer passes through the Surface. The Indigo follows next, and the other Colours do the same, as the Obliquity increases. The Red continues its Course longer, and is the last reflected.

From

110 DIALOGUE IX.

From what has been just observed we conceive, that God, who alone was able to form the exterior and sensible Surface of all organized Bodies, has also taken Care, in a Distribution truly immense, to regulate the Form, the Density, and Order of the very minutest Elements, of which their Masses are composed; that the Shape and Interstices of those minute Elements might preserve a just and an exact Proportion with the superlative Minuteness of the Particles of Light; and that these Particles, being themselves of seven different Kinds, they might sometimes rebound from these small Elements, sometimes cross their Interstices, and thus produce Effects always new and regular. From this noble Oeconomy, established in the Sensations our Souls experience; from that Order we just now admired in the Structure of the Rays of the Light; in short, from that which we cannot refuse to acknowledge in the very minutest Elements; I say, from these three Orders, established one upon another, and indeed useless without each other, the Sight and Use of Nature do result. For whose Sake then have so many Precautions and so much Care been taken?

THE

THE S H A D E.

DIALOGUE X.

ALL Bodies exposed to the Aspect of the Sun receive their Light and Colour from him. We moreover see these Bodies attended by a Shape inseparable from them, and which may in its Turn deserve our Attention. Shadow is not, like Darkness, a Thing of nought. It is attenuated Light; a more or less considerable Diminution of it, reflected from the Surface of Bodies, in a Place to which the Sun cannot directly throw its own. Laws invariable, and as ancient as the World, cause that Light to dash from one Body upon another, and from this successively on a third, and so on like Water in a Cascade, but always with new Diminutions of Force from one Fall to another. Were it not for these all-wise Laws, whatever is not immediately, and without any Obstacle interposed, under the Sun, must be immersed in total Darkness. While the Sun delights the Eyes of those who are in the Court of a Building, those who have a Mind to view the Inside, or the opposite Front of it, would on a sudden be wrapt in the darkest Obscurity; and the Transition, from the enlightened Side of

of Objects, to that which the Sun does not shine on, would throughout Nature be like the Passage from the Surface of the Earth to the Inside of Vaults and Cellars. But by an Effect of those powerful Springs, which God has prepared in every individual Particle of that thin Substance, it impels all the Bodies on which it falls, and is repelled thereby, on Account both of its Spring and the Resistance it finds from them. It dashes on and bounds from the Bodies it has struck and brightened by its direct Influence. From these it is carried on to those round about; and though it thus passes from the one to the other with a continual Loss, it shews us even those not exposed to the Sun. From one Surface to another, and from Turn to Turn, it at last reaches the remotest Recesses; and when it can no longer there procure us the distinct Sight of Objects, it still shews them us confusedly: It at last prevents our Falling, and informs us of all Dangers.

What the whole Mass of Light does in Nature in great, by changing itself into a Twilight after Sun-set, each individual Ray of Light does at every Instant, in transforming itself into a Shade by its several Dashings. Any Portion of Light which has already been of Use to us, instead of suddenly ceasing to be of Service, on the contrary prolongs and even varies it, as it grows weaker. These several Degrees of Force rule our Actions, and suit themselves to our Wants. The great Beauty and lively Splendor of the pure Light, makes us set our Apartments towards the Sun, from whom our Life and Health proceed. The darkest Side will serve to lay up in Store such Things as shun the Heat or a glaring Light. The Shade serves us to judge of the Situation of Objects, as well as to be the more sensible of their Distances: It seems to make two different Colours of one, by taking from it the Brightness it had in the broad Day-light. The Scarlet seems to change its Nature, when it comes into the Shade: It will undergo another Alteration, when it enters into a Shade that is deeper. All Bodies, even those of the brightest Colours, become darker, as they decline from the Influences of the Sun, and from the first Reflexions of the Light, which causes in every Part a Difference extremely useful. For in setting off an Object by the Help of a Ground, or of another Object next to it, more or less dark,

dark, it embellishes, characterizes, and distinguishes in our Eyes, what the Remoteness or the Uniformity of Colour would have confounded.

It is the Study of that Mixture, and of The Shades in those gradual Attenuations of the Light Painting. and Shades, which makes one of the noblest Parts of Painting. In vain would the Painter know how to compose a Subject, to place his Figures, and to draw the whole in a correct Manner, if he knew not, by the Attenuations and exact Degrees of Light and Shade, how to make some Objects draw near, others to sit back, and to give them all their Contours or Out-lines, their Distances and different Degrees of Strength, and the Appearance of Reality and Life. Draughtsmen or Designers, to express their Thoughts, only use weaker or stronger Shades. Engravers, in order to multiply the Copies of the noblest Pictures, use no other Colour than the White of their Paper, which they convert into as many Objects as they please, by the Strength and Degrees of Shade with which they cover it: Or else, they do the Reverse, and furrow the whole Copper-plate with large Strokes; so that the Paper they should apply thereto, when blackened, would from the Press present nothing but an uniform Shade, or a universal Black. They afterwards scratch or burnish out of their Plate, more or less of these Strokes. The weakened Parts of the Shade become so many Points of the Object; and the more these Points of Shade are flat and well razed, the stronger and the better heightened are the Lines of the Object.

Besides the important Service of conveying a greater Distinctness in the Picture of Nature, the Shade conveys with it every where another far greater Advantage; I mean, Coolness. This, with regard to Cold, is what Shade is to Darkness. Cold is no more than the Absence of Heat, as Darkness is only the Privation of Light: And as the Shade does not take the Use of the Day from us, the Coolness, which attends it, does not deprive us of the Use of a mild and moderate Warmth.

As the Summer comes on, and this Coolness becomes

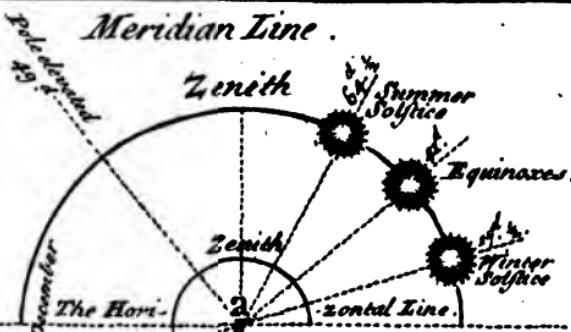
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necessary; God spreads and thickens the Shades which procure it for us. He gives Strength to the Leaves, and prepares convenient Covets, under which the drooping Flocks shun the Beams and Heat of the Sun. Man comes thither to refresh his exhausted Spirits: There he enjoys the Cool, without being in the Dark: There he continues his Work, without being deprived of the Sight of Nature. When the Return of Winter shall again bring him to his Fire-side, then shall the Leaves become useless to him; and then is the Time of their Fall: But Man shall see them spring again with his renewed Wants.

That Shade, so useful in its own Nature, becomes still more so by the Industry of Man, and by the Attention he gave

to the several Uses of it. When he sees it follow exactly all the Situations of the Sun; or rather, when he observes, that the Motions of the Shade are the same as those of the Rays which would fall on the Ground, were they not interrupted in their Course; he informs himself of the Path of the Sun, by that of the Shade: He makes the Shade of a Pyramid, a Style, or a Column to fall on Lines and on Points, where it shews him at one View, and without any Trouble on his Part, the Hour of the Day, the Elevation of the Sun above the Horizon, and the exact Point of the celestial Sign it is actually in. The Reason of which is easy to be conceived. Let us imagine in the Heaven a Point exactly over our Head, and which we shall call Zenith, after the *Arabians*, who, next to the *Greeks*, were our Masters in Astronomy, and have fixed the Terms of it. Let us set up a Pyramid or a simple Pole perfectly perpendicular; and let us extend it in Imagination up to the Zenith, by a perpendicular Line reaching from one to the other. If the Sun should come to our Zenith, one of its Rays would fall down that Perpendicular on the Pyramid; the Point of which opposing to that Ray no greater Obstacle on one Side than on the other, it would form no Shade. But if the Sun deviates from the Zenith, its Ray falling obliquely on the Top of the Pyramid, the Point of Shade made by its Top on the Earth shall be distant from the Foot of the Pyramid, in Proportion as the Sun shall be distant from the Zenith; and the Length of the Shade may then be called

the



A Meridian Line delineated upon a Parson of a gallery

Nadir.

From on
Decem.
10 of March.
12 of Septem.
From equin.
of Septem.
From equin.
of June.

2. This point is the top of a Gnomon, set up by the Extremity of its shadow to imitate several fallings of the rays of the Sun at noon, according to the several elevations of that Star.

This point 2. may be a small round aperture contrived in the top of a house or in a wall to admit a strong ray of the Sun which may indicate of progress or the altitudes of it by falling every day at noon upon a line delineated at an equal distance from the true points of East and West.

Round this point 2. considered as the center of the World with regard to us, you may have a circle whose plane is at an equal distance from the East and the West; and thereon take degrees that may be with regard to the Nadir or the inferior point, what if several altitudes of the Sun are with regard to the Zenith.

The lines drawn from the center 2. upon these points, and prolonged to the Meridian line, shall point out there upon the several fallings of the rays of the Sun, according to his elevation.

J. Mynde Sculp.



the Distance of the Sun from the Zenith for that Day. If the Length of the Shade varies from Day to Day, at the Moment of the Sun's greatest Elevation, when he is in the Meridian or at Mid-day, it may be calculated how much the Sun draws near or recedes from the Zenith in the Compass of a Year. That Shade on the 21st of June N. S. is the shortest, and on the 22d of December N. S. the longest it can be in the whole Year. All these Points of Shade, faithfully observed and marked, shall then be the faithful Image of the several Situations of the Sun in the Heavens, and the successive Inequalities of that Shade shall express the Succession, Order, and Limits of the Course of the Sun.

Instead of the Shade, we may make Use of a brisk Ray of Light through a Shade or Hole, which comes, and with its Extremity whitens and marks out, among Points and Lines drawn on the Ground or otherwise, the Place which relates to the Progress of the Day or of the current Month. Some use a small round Aperture in the Cieling or the Wall, having a South Aspect, on a Pavement or an inlaid Floor. They lay on that Pavement, rather than on the inlaid Work which the sultry Heat or the wet Weather always injures, a Lamina of Marble or of Copper, which directs its Extremities towards each Pole. This Line is called a Meridian-line; because it necessarily takes in all the Points on which the Ray of the Sun will fall every Day of the Year, at the Instant when that Star is equally distant from the Place of its Rising and that of its Setting. And as it rises or goes down differently in the Heaven, according to the Seasons of the Year, the Point of Mid day, though always received upon that Lamina, falls thereon higher or lower, according to the Situation of the Sun. This Variety is there expressed by so many Marks, which point out to you and exactly distinguish the Solstices, the Equinoxes, and the daily Distances of the Sun from the Aequator, towards either of the two Tropics, between which its Course is confined.

Such is that famous Line, which *Ignatio Danti*, a Dominican, delineated in the Church of St. Petrone of Bologna, Anno 1575, to mark out chiefly the Points of the Solstices and the Equinoxes, the Non-observance of which had disturbed

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turbed the Order of the Holy-days. That Line was placed in some other Part of the same Church, and infinitely improved by the great *Caffini*.

Of this Sort is the Meridian-line delineated at the Royal Observatory. Such are all those, which private Persons now make in their own Studies, or in any other Place, the better to regulate their Pendulums.

The dark Room. Another quite different Use of the Shade, or rather of the Light surrounded with the deepest Darkness, is commonly made. They put upon a Table a Kind of little Chamber or Tent, supported by Laths, and well closed with good strong Cloth. This Tent, which most commonly is made in Form of a Pyramid, is terminated by a large Glass of a lenticular Form, above which are two small upright Points, designed to support, and at Pleasure to incline a flat Looking-glass. The Rays of the Objects from every Side fall on this * Glass, whence by the just Disposition given them, they are reflected on the lenticular Glass, horizontally placed at the Top of the little Chamber. This Glass, which is thicker in the Middle than at the Edges, refracts and draws these Rays near each other, so that they paint in Miniature the Image of the Objects on the Bottom of the Room, whereon a Linen-cloth or a white Paper is laid, in order to give them more Strength. If you turn your Back to the Object, and put your Head under the Fore-curtain, but in such a Manner, that the Light cannot get into the Tent, the external Objects are seen painted there with all their Colours: It is not possible to see a more exact Prospect or Landskip whatever. It is Nature itself.

This

* This Looking-glass, being inclined so as to form an Angle of 45 Degrees with the lenticular Glass horizontally placed; the Rays which from the Objects come almost parallel to the Horizon upon the Glass, form with its Surface an Angle of 45 Degrees, and are reflected by a like Angle, the Reflexion being equal to the Incidence. Now these two Angles, and that which is between them, are equivalent to two right Angles; therefore the two Angles on the Surface of the Looking-glass being together 90 Degrees, the other between them is likewise 90 Degrees. But a right Angle, or one of 90 Degrees, is formed with two Lines, one of which is perpendicular to the other. Therefore the Rays, which fall upon the Looking-glass in a Direction parallel to the Horizon, are then sent back in a parallel Manner upon the lenticular Glass, through which they pass, and are collected at the lower End of the *CAMERA OBSCURA*.

This pretty Invention goes farther than mere Amusement. We may very usefully exercise ourselves, in delineating on a Paper the Out-lines of the Objects. We may place, at the proper Distance, a Person whom we order to put himself in this or that Posture, or take such or such an Air of the Head, and any other Attitude we may want: And it is not only an easy Matter to exercise one's self in the most difficult Parts of Drawing; but we shall likewise in a very short Time take the Profil and Prospect of a Castle, of a Landskip, or of a large Town with its Towers and Steeples. By this Means, you are sure of the Exactness of the Figures and Situations. You afterwards take the Time necessary to shadow each Piece, according to the Degree or Force it should have, or to colour the whole, without losing Sight of the Original you copy after. Thus Nature proves the most learned and most convenient of Masters to us.

It is an easy Matter to make of Shade another, indeed less entertaining, but sometimes more necessary Use. You have a Mind, without giving yourself any Trouble, and without any Instrument, to know the Height of a Tree, a Building, a Steeple, or Hill. The Shade of these Objects will immediately acquaint you with the Truth of the Matter; provided you do not make the Operation immediately after the Rising, or before the Setting of the Sun; because the Shadow at that Time shortens or lengthens so suddenly, that there would be a Mis-reckoning from one Moment to another.

Thrust into the Earth a Stick perfectly upright and perpendicular. Measure the Shade of it. This is either longer, shorter, or equal to the Stick. It will be with the Shade of the Tower compared with the Height thereof, as with the Shade of the Stick compared with the Height of the Stick itself. Measure the Length of the Shade of the Tower, which suppose you found to be twelve Fathoms. After having in the same Manner measured the Shade of the Stick, divide the last Length into twelve equal Parts, which we shall call Inches, Minutes, or any other Name you please. By applying that Measure to the Stick, you, for Instance, find that it is but ten Inches, or ten of those equal Divisions or Parts. This being so, the Shade of the Stick is of Course two Inches longer than the Stick itself.

To know the Height of a Tower by its Shade.

The Shade of the Tower does then likewise exceed the Height of the Tower by two Fathoms, and thence you are unquestionably informed, that the Tower is ten Fathoms high. If, on the contrary, the Shade of the Tower happens to be eight Fathoms, and the Stick to exceed by two Inches or Parts its own Shade, which you shall have divided into eight equal Parts, it thence follows, that the Tower is by two Fathoms higher than its Shade is long: It is then ten Fathoms high. Finally, if the Stick is equal to its Shade, and the Shade of the Tower, immediately measured, proves to be ten Fathoms, you may, without any other Calculation, be certain, that the Tower and its Shade are equal, and that its Height is ten Fathoms.

This Comparison of the determined Height of a Pyramid, or any other Gnomon (or Object set up, to inform us of something by its Shade) affords us an excellent Method of fixing certain Points of Geography. For Instance: If we know, from faithful Memoirs, the Proportion which is at *Pekin*, between a Tower a hundred Feet high and its Shadow, on the Day of the Summer Solstice at Noon, and at the same Time find another Proportion at *Paris*, between a Gnomon one hundred Feet high and its Shade; from the Difference of these Proportions we are informed, how much *Pekin* is nearer than we to the Line which bounds the Course of the Sun. For the nearer a Place is to the perpendicular Fall of the Rays of the Sun at Noon, the shorter likewise in that Place will be the Shade of the Towers. We may then judge how much nearer one Town is to the Point of the Solstice than another, from the Inequality of the Shade of two Towers of the same Height, under the Meridian Sun of any particular Day.

Though the Art of Man contributes something to these several Operations, it consists only in observing the Motions of the Light, and in making Use of the Helps which Light affords us. The Fluid, in some Measure, wherein all these Lines and several Directions subsist, touches us immediately: But the Source of those regular Motions, which are there perpetually operating for us, is thirty-three millions of Leagues distant from us.

T H E
P L A C E and U S E S
 O F
F I R E.

D I A L O G U E XI.

GOD, by the Manner in which he has framed and placed the Sun, has made it the Center of the Dispensation of that Day and those Colours, which were to render the World visible: But this profound Wisdom, which delights in bringing a Multitude of great Effects out of one and the same Instrument, has designed moreover the Activity of that wonderful Globe, to distribute throughout the Earth the just and exact Quantity of Heat, which therein gives Life to Animals and Plants. It is true, Heat can create nothing. Organized Bodies are not indebted to it for their Structure; and the Elements, which nourish these organized Bodies, have also their peculiar Nature independent on Heat. But it is with good Reason, that Heat is styled vivifying; since God has appointed it, to set the Element at work, and to assist organized

ganized Bodies in their Unfolding, Growth, and Perfection. It is that Heat which gives Birth to the Winds, by dilating the Air. It is that, which, by raising the Water on high, every where conveys Coolness, Refreshment, and Plenty. It is that which makes Men long to enjoy the Sun, which bestows on them not only fine Days, but even Breath and Life. We all of us, without the Help of any Arguments or Inquiries, are sensible of the secret Relations, which are between the Heat of the Sun and our Life. We value our Habitations, only as they enjoy the Aspect and Influence of that Star. We have no Opinion of, and distrust such as are but obliquely influenced by it. When they are totally deprived of it, we compare them to Tombs: And it is because the Sun warms whatever it lightens, that we stile it the Soul of Nature.

But let us not entertain an Idea of it more advantageous than Truth will admit; and let us be sure not to fall into the same Mistake as those Nations and Philosophers did, who honoured it as the Father of Light and Fire. In the great Remoteness of the Sun, and in the darkest Night, we still have the Use of Fire at our Command. There may be then at least one Sort of Fire, which we do not always receive from the Sun the Moment we use it; and it will perhaps be the same with the Fire or Heat which we experience in Presence of the Sun, as with the Light itself. We have remarked that Light was not any Emanation of the Substance of the Sun: That it was before, and not in it: That it was as effectually round us during the Night, wherein the minutest Spark of Fire renders it sensible to us, as it is in the broad Day-light, when the Sun pushes it violently upon us; in short, that the Sun is not, any more than a single Spark, the Mover of the Body of the Light. Though the Light should in itself then be a real Fire, the Sun, which pushes it towards us, would at most be only a magnificent Instrument, designed to communicate to a great Distance the Use of the Fire, by the Universality of the Impression it gives the Light; and we shall always be forced to look higher than the Sun for the Principle of that immense Action, and the Original of this noble Oeconomy.

But the Intention which has formed these Springs, and the Hand which governs them, will become more sensible

to you ; nay, you must needs be amazed at the Consideration of the Precautions so wisely taken to secure the Length of our Days, when I come to shew you, that, besides the Light which fills the Universe, God has placed near us, and purely for our Sake, as well in the lower Strata of the Air, as within the Outer-crust of our Earth, an Element full of Force and Activity, which we shall call the terrestrial Fire : That it is this Fire which is the constant Support of our Life : That it owes its Existence neither to the Sun nor to the Light ; and that what it receives from the Sun, amounts to no more than a stronger or weaker Impulse, which it receives from it, by Means of that Fluid the Light, which extends from one to the other.

To avoid all Disputes, I shall grant, if you please, that Light is a real Fire, and that it can both burn and give Light, in Proportion as its Activity, or the Impulse it has received, is greater. You may call this the celestial Fire, if it burns by itself, and not by Means of our Fire. But it seems to be evident, that there is a terrestrial Fire, very near us : That it enters more or less into the Composition of terrestrial Bodies : That it is dispersed through the whole Mass of the Air, especially of the lower Air : That it is not perceptible in terrestrial Bodies, so long as it remains imprisoned therein : That it is not visible in the Air, so long as it is in Equilibrio, and equally distributed therein ; but that it breaks out, when it is agitated or confined ; in short, that, far from being the Light, it has the singular Property of being pushed and acted on by the Light when agitated, and of making, in its Turn, the Light shine by repelling it. I shall rather make use of Matters of Fact than Arguments, to convince you of those extraordinary Means, by which God preserves Mankind, and in which we find the affecting Proofs of a Benevolence, which could have no other Object than ourselves.

1. We may experience a very genial Warmth in a very dark Place, and convey the brightest Light through the Windows of a Room wherein we feel an excessive Cold.

2. The Fire, which comes out of a German Stove, sensibly affects us, without making the least Impression on the Eye, otherwise so easy to be affected ; because that Fire, though abundant, is much dispersed, equally distributed, and incapable of pushing the Light upon our Eyes ; ex-

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cept where it is agitated, confined, and accelerated. On the contrary, the Light reflected by the Body of the Moon makes a strong Impression upon the Eye, without having however the least Heat. Here is then a very plentiful Fire without Light, and a very bright Light without Heat.

3. But it is an easy Matter to disunite the terrestrial Fire, and the Light still more. Let us place ourselves on the Top of the *Alps*, or on the *Pico of Teyde* in the Island *Teneriffe*, almost at the Entrance of the Torrid Zone; or rather still on the Top of the *Cordilleras* in *Peru*, which is in the very Middle of the same Zone, and on the highest Mountains in the Universe. You imagine, as you ascend, and more and more approach towards the Sun, that you are going to experience a greater Heat. But I advise you not to venture that Journey slightly cloathed: For, I must tell you, you may not be absolutely free from shivering under the warmest Furs. The more you shall ascend, the sharper will the Cold appear to you. The Air of the *Pico*, under the twenty-eighth Degree of Distance from the *Æquator*, is sharper, though without Wind, and in the Month of *August*, than the Air of *London* under the fifty-second Degree of Latitude, and during the hardest Frosts that were ever experienced there. This Fact, attested by very credible * Witnesses may serve in some Measure to determine whether the Body of Fire comes from above, or resides below. But as you might be inclined to think, that the Force of the Light is owing to the Reflexion of the Plains, instead of a Mountain terminating in a Point, let us chuse the *Cordilleras* of *Peru*. You are not to imagine then so many irregular Pyramids. We on the contrary find there very spacious Plains, several hundreds of Leagues in Length, and which being higher than the Region of the Clouds, and terrestrial Vapours, are covered with a pure Light, which must needs be there very active and powerful; falling on it every Day almost perpendicularly: No Wind can come there to weaken, or Fog to blunt it. Nothing, in short, can be

more

* The Air at the Top of the *Pico*, was as cold as I have known it in *England* in the sharpest Frost I was ever in. Extract from the Relation of the Voyage made to the Top of the *Pico*, by M. *J. de la C. Philosop. Transact. abridged*, Vol. v. ii. Pag. 147.

more sharp and lively than the Reflexion of that Light. Yet those Places are destitute of all Heat. It cannot so much as melt the Snows which lie beneath on the Declivities, or assist the Production of any Plant whatever. No Traveller ever ventures on this dangerous Journey, without covering himself as warm as he would be in the North. He sometimes is frightened on finding Men and Horses dead with Cold, which continue stiff and uncorrupted for several Years together, in Places perfectly inaccessible to Heat, Rain, and Insects.

Were Light the same Thing as our Fire, the Heat always would increase in Proportion to the Light, when it is not crossed by the Wind, or intercepted by any Clouds. Here is however an extremely brilliant and perfectly reflected Light, which yields but little, or rather no Heat at all. I have then still the greater Reason to think, that if the Light, which we receive in our Climates, is therein accompanied with great Heats, it is because it pushes towards us a Fire which it finds there, and which does not abound so much in more elevated Places.

4. And really, as I descend from the Top of these cold Mountains, (and we find the same thing also in coming down the *Alps* and the *Apennine*) I breathe a milder Air. I proceed to Places, where the undermost Snows begin to melt, while the uppermost remain impenetrable to the Light, how bright and glaring soever it may be. As I come still lower, I perceive a little Grass, and the Fertility increases together with the Impressions of the Heat. Soon after I walk across Herbage and Woods; and at last I am (though the Sun be just up) obliged to rid myself of the Burden of my Cloaths, which overweigh me, whereas they scarce could shelter me against the sharp Cold of the Upper-grounds. The Change I experience, as I draw nearer the Plain, is then in the Fire itself, and not in the Light. The Fire abandoned me before, as I went from the lower Lands, and every Thing, as it were, invites me to confess it must reside there.

My first Suspicion is confirmed from other Experiments. A burning Coal, which, being offered to the Focus of a spherical concave Glass, darts its Heat by parallel Rays on another Glass placed at forty, or even

fifty Paces Distance, sends thither a sufficient Number of them, by a reflex Fire, to burn a few combustible Matters in the Focus of this last concave Glass: Whereas the Light of the Moon, heightened by the Re-union, and giving in the focal Point a Degree of Brightness, which Messieurs of the Academy of Sciences judge to be five hundred Times greater than that of the Full Moon, warms nothing there, nor does so much as cause the least Agitation imaginable in the Liquor of the Thermometer, which even the Approach of the Hand is capable of raising. A very little Fire then displays a greater Capacity for burning, than a very great Light does: And who knows but the Light does not burn by its own Power, but by the Mediation and Interposition of the Fire it pushes forth, when it is come up to a certain Degree of Activity, or when, being bent in the Convexity of a Glass, it unites its whole Force in a single Point, and there strongly quickens the Fire it meets with, because this resides in the Air?

Let us not degrade Light: Let us suffer it to enjoy the Reputation it has, of being able to warm and burn in Proportion to its Strength. How questionable soever this its Prerogative may become, from the foregoing Experiments; it is enough that we have made it good, that there is a terrestrial Fire, amidst which we live, which becomes sensible when the Light of the Sun presses on and pushes it towards us, and which makes the Light shine in the Middle of Darkness, when it is with Violence carried against it.

6. The Light without any Hindrance passes through Crystal, Glass, and Jewels. But most of these transparent Matters cease to be so, the Moment the Fire penetrates through or makes them red; and that Fire, very far from being the Light, does then actually reflect and entirely repel it, without yielding it any Passage.

7. The Light of the Sun, which shines with but very little Heat, even in the Midst of Summer, on Mountains, where it finds less Fire to press, so swiftly throws down upon us the more abundant Fire it finds in the lower Air, that it renders it furious, and make us suffer sultry Heats, even when it no longer shines above our Horizon, and when the Night is come. Was Light Fire, we should have excessive Heats, before as well as after the Solstice, and in

May as well as in July. The Light, at the End of these Months is equally brisk and active: That at Nine o'Clock in the Morning is the same as at Three in the Afternoon. But the first only begins to quickens the Fire, whereas the Fire violently agitated, still maintains its Fury a long Time after the second is gone. The Light does then only irritate the Fire, and is not the self-same Thing with it.

8. What makes us confound them is, the Custom of seeing them scarce ever asunder. Above all we are apt to believe that a Stroke of Light is in itself a Stroke of Fire, when we see it pass through a lenticular, or reflected from a concave Glass, and there burn or calcine what is offered to the Focus. But the Light is not of itself perhaps more burning in that Point than in any other: It is true, its Activity and all its Efforts are centered there. It prodigiously quickens the small Quantity of Fire which it finds there, and which, as it were, it keeps closely imprisoned. It adds Rage and Power to the Fire it finds there, but does not bring it thither; or if it there precipitates the Fire from several Points, yet there is no Argument, why we should confound it with the Light.

9. So many are the Proofs we have produced, to shew that Light is dispersed throughout the Universe, and that it is present every where, even when it is unmoved, and in Appearance void of Action: So many certain Evidences have we to convince us, that the Fire has been placed for our Service, not above the Air, as Aristotle thought, or in the Light, as we are apt to fancy from some doubtful Appearances, but in the lowermost Regions of the Air, in the Neighbourhood of the Earth, and to a certain Depth in the Earth itself.

Neither need we fear that this precious Element, the true Support of the Life of our Bodies, (and who knows but that it may be that Life itself?) should be any Way hindered in its Operations, from its having been placed in the gross Air, in the Water, and in the Earth. How these Elements are constructed, I indeed know not: But what strikes every attentive Eye is, that the Structure and Artifice of them is such, that they unitedly produce the noblest Effects, and that oftentimes the one is perfectly void of Power without the Assistance of the other. Light increased accelerates the Motion of Fire: The Fire col-

lected dilates the Air; the dilated Air raises the Water, the Oil, and the Salt. All the Elements blended together roll in the Atmosphere, whence they spread all over the Earth, and scatter their Blessings on every Part of it. You see at one View the Consequence of this wise Mixture.

Though perfectly impenetrable by our Understanding, it is demonstrated by Matters of Fact; and it is in particular an unquestionable Truth, that the Element of Fire resides in the Air we breathe, in the Water we drink, and in the Earth which nourishes us. The Air, when deprived of Fire in receding from the Earth, becomes intolerable: The Water, no longer supported by this Fire, refuses to flow for our Use, and by freezing becomes as hard as a Stone: And the Earth, destitute of it, is a heavy Mass, void of Action and Utility.

Fire dwells in the Bowels of the Earth, at least to a certain Depth: It rushes out of it, through the Crevices and Openings of Volcano's. The Water carries it, together with the Sulphur, a great Way from the Iron Mines. It is washed from them, and we see it issue together with the Mire of hot Baths. It is not less real, for its apparent Inactivity in the Filaments of Sulphur, in Fat, in Woods, and in all vegetable Bodies. A brisk Shock discloses the Fire, which resides even in the Bowels of Flints, or at least the Fire of the Air, which is catched between the two Points that strike against each other.

The rubbing of Glass Tubes, or of the Axle-tree of a Wheel, not only heats them, by quickening the Fire, which makes a Part of their Substance; but even displays Particles of that Element, oftentimes capable of causing a Conflagration. These Sparks, fetched either from Stones, or out of the Air, and violently agitated against each other between two Mill-stones without Corn between them, acquire a Degree of Force capable of setting the Timber-work and adjacent Buildings on fire.

There is no Body, how apparently soever destitute of Fire (as Marbles and Metals are) but what grows hot by violent Motions, not only by the Agitation caused in the Fire that is therein, but also by the Communication of the Fire, which is heightened in the agitated Air, and in the ambient Bodies. Clashings and Shocks are not the Fire, but serve to let it loose, by agitating or crushing the Bubbles

Bubbles of Air, and the little Cells which contain it. All Bodies may be equally agitated or pressed ; but all are not therefore equally combustible. They are the more apt to take fire, as they contain a greater Quantity of that Matter, and as that Fire, whose Force consists in its Velocity, acquires a greater Motion by its Agitation.

The Fire is then under our Feet, and all around us, always ready to serve our Purposes ; we lose it in Proportion as we get above the Plains, where God has fixed our Dwelling ; and it is a very pleasing Consideration for us to see, that in finding out the true Place of this so beneficial and so comfortable a Fire, we at the same Time find out so evident and so well distinguished an Intention in God, of placing it within our Reach, and of keeping it always in a Readiness to answer all our Desires.

These Proofs seem sufficient to make me renounce the Prejudice, which confounds our common Fire with Light : And though I conceive not the Nature of either of them ; I shall sufficiently distinguish between them, if I am but sensible of the Difference of the Place they take up, and of the Functions they are appointed to discharge.

Fire and Light then dwell around us, since in the Night, as well as in the Day-time, and without the Help of the Sun, we make use of them, and always find them at Need. But the Place of the Fire, which we use, extends not to a greater Distance from us : The Place of the Light, on the contrary, extends to the very Stars. The Activity of the Fire spreads but a little Way, and it sensibly ceases to act, when it is ever so little scattered : The Activity of the Light, on the contrary, extends to an almost infinite Distance. These two Elements, when in Repose, and not externally influenced, keep between themselves a Sort of Equilibrium : They touch without clashing against each other ; they are under our Hands, and before our Eyes, without being either felt or seen. But one of them cannot be strongly agitated, without causing an Agitation to the other ; and their reciprocal Power increases in Proportion to their Quantity, and the Strength of the Impression received. The Narrowness of the Compass, within which Fire is accelerated, still contributes to increase its Fury. The Fire in a German Stove causes no Conflagration in adjacent Bodies, nor any Emotion in the Light, as it is dispersed

persed at Liberty and in a true Equilibrio. Whereas that small Parcel of Fire we call a Spark, is so violently agitated between the Part of the Flint where it is struck, and the Pieces of Steel which fetches it out, that it melts the Metal, and shakes the Body of Light, so as to make it appear at a hundred Paces round it. We find these melted Particles of Steel, in the Paper over which we have struck a Light: The Microscope, which shews us their bright and unrivalled Figure, is a Proof of their having been in a State of Fusion.

When therefore Fire and Light are in Equilibrio, their Quietness insures our Safety and Repose. The Disorder of the one can no sooner be communicated to the other, but they both acquire a Force designed to procure us some Advantage, or to warn us of some Danger. The increased Light keeps the Fire from being inactive. Thence the Motion and Fertility of Nature. The minutest Particle of Fire violently forced out of a Flint, receiving from that Shock a Force sufficient to melt the Particle of Steel which strikes it out, has also a Force sufficient to agitate strongly the Light, which immediately communicates its Agitation to us: Whence the perpetual Warnings we receive from it. When the Fire is but little, it is only a gentle Glimpse: But its Splendor becomes terrible, when there is any great Danger. It seasonably reveals all the Operations of that dreadful Element: It declares it afar off, and long before its Arrival. It gives us Notice of the Havock it may make; and because Fire has a Fury capable of causing a general Destruction, it is, that Light was placed near it, as a watchful Centinel, which prevents by a salutary Alarm the Disasters it would bring upon Men. It is true, the Lightning does not in Time warn the Man that is thunderstruck; but it, at least, warns others to acknowledge the Hand of him who both strikes and spares.

How much soever we may be beholden to the Light for the faithful Advices it gives us: yet let us not look upon Fire as an Enemy. It is, on the contrary, an estimable Gift. It never is offensive in Man's Hands, but when ill-managed; and in God's never hurts, but according to the wise Purposes of his Providence.

The Uses of Fire are too common not to be known. But is it not enough to know them in a loose and confused

Manner?

Manner? Let us trace Fire in the Par icularity of its Operations. We shall be amazed to see the Varie.y of Forms it puts on to serve us, and the Associations it suc-cessively makes to fulfil our Wants, very often without shewing itself.

The Action of Fire is sometimes helped and accele-rated, sometimes restrained and bridled by the Air, the Water, the Oil, and the Salt.

Of all the Elements, the Air is what Fire can least do without. The Air, it is true, does not give Fire its Being and Birth; but it helps its Action, and makes it appear where it subsisted unseen. Fire enters into the Composition of all terrestrial Bodies: It can go through several of their Pores, and having entered them, may be transported with them from one Place to another. But its not appear-ing in the Bodies it heats, or the Air wherein it dwells, proceeds from its being there dispersed in a Sort of Equilibrio, and in a Quantity which makes it not sufficiently active to be taken Notice of. It neither shines nor is perceived therein, because the Light is commissionned to shew it us, only when it rages and is dangerous.

It becomes so, either by the Increase of its Quantity, or Velocity. It no sooner is gathered or quickened any where so as to dilate the ambient Air, but that Air con-tributes to the keeping it in. First, because it confines that Fire in one Place, and hinders it from getting loose so soon as it would without Air. We therefore see the Flame of a Wax-candle distinguishing in the Recipient of the Air-pump, in Proportion as they exhaust; and disappearing and dispersing itself very easily, on the Removal of the Air. Secondly, the Air nourishes the Fire or the Flame; be-cause being itself full of Particles of Oil, which are like so many Cells full of fiery Matter, it thus supplies the Fire with a Multitude of minute Rivulets of the same Element, which are drawn towards the Place where the Fire is col-lected and strongly agitated; much in the same Manner as the Water of a River, or a Reservoir, moves from all Sides towards the Place where its Equil.brium is disturbed. All flows successively towards the Hole of the Flood-gate or of the Pump; and so much Water as goes out at a single Place, so much is again supplied from a thousand. The Fire lighted, that is, collected in a certain Place, there

remains; because so much Oil as it has dissipated, by scattering or wasting it on every Side, and especially above, so much new Oil does the circulating Air replace below. Therefore a Circulation of Air is really a Circulation of Fire. For this Reason it is, that you see the Flame of a Wax-candle always inclining towards the Fire on the Hearth, when it is any thing brisk. Wherefore, if you hold a lighted Wax-candle in a large Tube, wherein the Air freely circulates, it will continue burning there: But if you put it in a Tube which it exactly fills, the Fire which gets loose at Top will push away the Air. This, in the Reflux, will strike against the Sides and lower Part of the Tube, where finding the Passage shut, it will no longer supply the Flame with Fuel; and this shall immediately go out. For the same Reason People, who work in the Mines, are very careful to place at the Entrance or Mouth very large Sails, which the Wind may be able to move, and which, by their Agitation, always drive fresh Air into the Bottom of the Mines. Their Lamps would go out, for want of that Assistance; because the Fire quickened spreads presently, and would soon be dispersed, were it not replaced by some other, which is quickened in its Turn by touching the Mass of the Flame. Without this Renewal of the Air, the Workmen would not only lose their Lights, but even their Lives, which consist in a Fire which the Air kindles, and which would let the Blood coagulate, were it not preserved therein by a continual Supply of fresh Air.

The Necessity of the Circulation of Air, for the maintaining of Fire, is very obvious wherever Fire is lighted; but chiefly when the Fat of Soot happens to take Fire in the Funnel of a Chimney, and threatens the whole Neighbourhood with a Conflagration. If then the Opening of the Chimney be not excessively large, as they were made formerly, you may be sure to stop the Fire almost instantaneously, by stopping that Orifice with a Heap of Dung, or even by immediately spreading a Wet Sheet before it, which by the Plenitude of its Pores shall bar the Passage of the Air ready to go up the Hollow. They pretend, but I would not warrant it, that the firing of a Gun up a Chimney on a fire, scatters the Air so violently below, that the Fire spreads and is dispersed; before the Air pressed and

and pushed away can return. You give the Fire, which breaks out in a Cellar, the Means of quitting the combustible Matters it devours, and of scattering along and through the Walls, by barring up the Entrance of the external Air into the Vents, with a good Quantity of Straw. They very often have put a sudden Stop to a Fire which had seized on a whole Room, by bringing in a Barrel of Water, in the Center of which was suspended a Box full of Gunpowder; the Fire of the Match dipt in Brimstone, which they convey to the Powder through the Water, by Means of a long Tin Pipe, no sooner touches it, but the inflamed Powder violently drives both the Water and the ambient Air. The Air, thus driven away and pressed, is not restored, nor does it return to its Place, till the Fire is dispersed and out, for want of something to contain it. Nay, the Water perhaps, in that Case, absorbs a Part of it, which deprives the rest of all Power.

We are amazed on seeing a violent Fire, which consumes whatever it meets with, and Hail-stones hard enough to remain unthawed for several Days together, rushing out of the same Cloud. So soon as the Fire of the Oil and the Sulphur which is exhaled into the Air, begin to fire these Matters by its Acceleration between Clouds which are pushed by contrary Winds, that Fire dilates the Air, and scatters it afar off, with a most dreadful Fulmination. All the Space abandoned by the Air remains likewise void of Fire; because Fire is never confined but by the Air. The Drops, which that Moment cross the Space void of Fire, lose all their own: They are frozen in an instant, and follow the Thunder-clap very close.

Air maintains the Fire, not only by pressing it enough to detain it a little in the same Place, or by perpetually supplying it by Circulation with a Course of subsidiary Fire, but also in accelerating the same Fire, by perpetual Shocks. For as the Air cannot feel the Acceleration of any Particle of Fire, without dilating; it is immediately repelled by the ambient Air. These Shocks multiplied in Proportion to the Quantity of Air, clash against the Fire, which thereby acquires a great Increase of Velocity, wherein the Force of that Element consists. For this Reason it is, that the same Air is not very long fit for the Support of Fire. For when it is dilated, it has no longer

the same Activity, as when it was confined? Whence it happens, that a burning Fire-brand is sooner put out in the great Light of the Sun, than in the Air of the Night, which is more fit to confine the Fire. For this Reason it is, that cold Air makes the Fire so very brisk. It likely contains less Fire than in the Summer-time, but it unbends itself much more violently against the Fire it meets with, and increases the Activity of it.

It is in order to procure this fresh Air, that we keep the Funnels of our Chimnies broad enough to contain on one Side the Column of Smoke which the Fire causes to ascend, and on the other a Column of Air which descends. It is in order to be still surer of the Return of the external Air, that we sometimes lay into the Wall next to the Chimney a Pipe of Tin or of Iron Plate, that may by one End admit the external Air, and by the other convey it into the Hearth, where it animates the Fire, and affits the Dissipation of the Smoke. In Consequence of the Want of Air, we blow and agitate the Fire we have a Mind to kindle. But that Agitation ought to be proportioned to the Quantity of Fire which was gathered at first. If it is but small, an excessive Agitation might extinguish instead of increasing it. The Blast, which animates the Fire on the Hearth, would presently put out the Flame of a Wax-candle. But how can the same Fan equally cool us, and light our Fire? The Fan does no more than this, *viz.* press the Air by driving it away, and makes the Fire flow out of it. For as the Inſinuation of the Fire into the Air dilates the latter, so likewise does the contracted Air cause a Part of the Fire, which it contains, to fly off. That Air therefore cannot be pressed upon us, without becoming somewhat cold, and without seeming to us charged with a less Quantity of Fire than before. But when the contracted Air, instead of affecting our Senses, immediately clashes with the Fire itself, which is gathered in any Place, it increases the Motion of it. Now the Measure of the Velocity of Fire is the Measure of its Strength. Whence it happens, that a Conflagration, which might have been stopped, had the Air been at rest, in a Moment becomes superior to all Efforts, if it be but assisted by a high Wind. The Velocity it then acquires becomes of fatal Conſequence. The Buildings which stop it, by confining its Activity,

Activity, and supplying it with new Fewel, increase its Fury. Far from leaving the Spectators the Liberty of affording Help, it scarce gives them leave to escape. A Sheet of Fire, driven off by a sudden Gust of Wind, very often surprises, at great Distances, those whose Fears their Remoteness had banished.

You will not infer from hence, that the Wind should always set the Air on fire. It, on the contrary, makes it always more or less cold, because the Fire is no where collected in it, but equally dispersed, in a Sort of Equilibrium. The Wind does not blow towards any particular Point, but at large; and if a greater or less Quantity of Fire is gathered between two contrary Winds, it is a little or a great Flash of Lightning, sometimes a Flood of Fire, or Clap of Thunder. You are also to remark, that there is no Wind but what cuts, and more or less retards the rapid Fall of the Light, and renders the Impression of it less powerful on the Body of Fire dispersed in the Air. All Winds in pressing the Air towards us contract it, and make it seem colder to us. The Northerly Winds, which blow from on high upon our Climate, press the Air down towards the Earth. The uppermost Strata press upon the lowermost, and make the Fire come out of them, just as the Water comes out of a squeezed Spunge. That Fire ascends higher, and so the Air having less Fire, necessarily contracts the Earth, and makes us feel a most severe Cold, when, being but lightly cloathed, we let that Fire vanish which our Blood stood in need of. The Southern and Westerly Winds, as they cross over very spacious Seas before they arrive on our Coasts, there drive before them, and every where disperse inconceivable Collections of watery Particles, which blunt and partly absorb the Action both of the Light and Fire. The Winds that blow from the Land, or which do not reach us before they have crossed over spacious Regions, are drier, and temper the sultry Heats of the Summer, in Proportion as their Blasts press the Air by their Strength; or they render the Heats stifling and intolerable, when, instead of breaking and blunting the Action of the Light, they, by their Repose, leave it the Liberty of darting on us all the Fire with which we are surrounded.

Fire, which, in Conjunction with the Air, varies our Seasons, and so powerfully influences either the Fruitfulness of the Earth, or the Health of Men, still produces, and by Means of Water, Effects full as important, though more concealed. Water is beholden to Fire for the Principle of its Action; since it owes its Fluidity to it, which it always loses on the vanishing of Fire. It is very probable, that Air is concerned in it, and together with the Fire, contributes to render Water fluid: For you no sooner put Water into the Air-pump, and exhaust the Air, but that which is in the Water, being freed from the Pressure of the external Air, gets loose, and raises the Water, by dilating it into small Bubbles; and if that Water is heated, the Air driven out of the Mass of Water by the Fire, makes the Water boil, as if it was on a violent Fire. After that boiling, the Air which remains in the Interstices of the Water, will be quiet, and without any apparent Elasticity, because a Quantity of Water is eight hundred and fifty times as massy, and consequently as heavy, as a like Portion of Air.

Water can by no Means be compressed like the Air, so far as to take up a less Space than it ordinarily does. If you fill a Pewter Ball with Water, and beat it with great and repeated Blows, it will sooner burst than flatten and contract the Water, by the Diminution of its Bulk. But then again Water, though it cannot be compressed, may be greatly dilated. It may, by Means of Fire, which more or less insinuates itself into it, acquire an Expansion, and of Course an Elasticity in a Manner infinite. That it has in itself no Spring, I shall readily grant: But it receives from Fire, which whirls in its Pores, a perpetual Tendency to dilate. That Elasticity or Expansion of Water manifests itself, the Instant it is in the Air-pump, and freed from the Air that pressed it.

Water not only bubbles up in the Vacuum, and on Fire, but there are also thousands of Particles of Water and of Air, which perpetually fly off from the heated Water, and grow round like Foot-balls. You know what they become in a more contracted and denser Air than they themselves are. We have formerly discoursed at large on the

the admirable Effects of their Evaporation, and of their being poised above: What we are here to remark is, that Fire is the Mover and Causē of both these. It is that Agent which God employs uniformly to set at work that Pump which raises the Water, and universally distributes it on the Outside of the Earth, there to nourish the Animals and Plants, and from thence in the Bowels of the Earth to convey into it the Salts, Oils, Sands, Mud, and metallic Particles, the various and continually renewed Assemblages of which are the Riches, and Support of Mankind.

Water and Air, if left by themselves, would be as it were inactive and void of Force: But being joined with Fire, they acquire Powers capable of shaking and overthrowing every Thing.

The Globules of Smoke, which Fire brings off from the Wood, and which are nothing but Air, Water, and rarefied Oils; when they meet in the Chimney with the Laminæ of a Wheel made of Iron Plates, and horizontally placed on a Pivot; these Globules, I say, if constantly pushed by the Flame which is kept beneath, have Strength enough to shake and push out of their Way the Laminæ of Iron Plate that bar their Passage. The Smoke which the Flame drives forward, striking with redoubled Blows against all the Laminæ which are inclined the same Way, there results from all these little and uniform Impulses a powerful Motion, which sets the Wheel a going. The Axis then which passes through the Wheel, and takes in a Pinion of six Teeth, turns another Wheel of thirty-six Teeth. This second Wheel, together with the Spit, which is made subject to all its Motions by Means of a Line, can make but one Revolution, while the Smoke-wheel is performing six. The Machine, without any other Help than that of the Smoke pushed by the Flame, thus goes on turning very large Pieces of Meat; and roasts them very regularly, without confining the Servants on that Account to any troublesome Care. The going out of the Fire stops all; But when the Fire is out, the Meat on the Spit is in no great Danger of being burnt.

The Impulse of that light Smoke, which borrows all its Force from the Shocks given by the Fire, help us to guess what Jerks and Shakings very little Vapours may produce,

produce, when they are accumulated in the Mines or in the Air, and when the Fire, getting loose within them, pushes them with Rapidity against whatever is about them.

But if Fire, always ready to be dispersed, and of too fine a Nature to act violently of itself, yet strikes such violent Blows, when it drives away and removes the Body of Air and that of Water, both much denser than its own; its Action still becomes infinitely more formidable, when it joins the Force and Strokes of Salt to the Spring of the Air and the Water. The inflexible Particles of that Element are like so many Hammers, Wedges, and Levers, which it sets at work. A very narrow Compass may contain thousands of millions of Particles of Fire, of Air, of Water, and of Salt-petre. All these Principles are found in Gunpowder: Nor is Water excepted, since in the Dissolution of it we find them there. The Particles of Fire and Air, which strive also to fill each of them five or six thousand Times more Room than before, and which are at Rest so long as they are separately imprisoned, no sooner feel the Impression of an external Fire, but they act all in concert; and by the Union and Concurrence of their Springs, by the immense Acceleration of their Velocities centered in a very narrow Space, and finally, by the Multitude of little Surfaces of Water and Salts which they dart, make an inconceivable Sum not to be reckoned up, but of which we may judge by the throwing of a Bomb, or firing of a Bullet, which, in a few Seconds, is flung to the Distance of many hundred Fathoms.

The fulminating Powder. The Power of Fire joined to the Air and the Water, when these Elements are confined by a great Quantity of Salts, and animated by the Introduction of a new Fire, appears still much more in the *Pulvis fulminans*. Pound three Parts of Salt-petre, as for Instance, three Ounces; two Ounces of Sulphur separately pounded, and as much of Tartar, which is that Salt which sticks to the Sides of the Vessels in which Wine has been Kept. Blend these three Powders together; and having put this Composition in an Iron Spoon on the burning Coals, retire. The whole gradually melts in the Spoon: But the Fire of the Sulphur, and the new Fire, which joined to it, being stopped and

and confined within by the acid Salt of the Vitriol in the Sulphur, and by the little Waddings of the Salt-petre and the Tartar, are, by the constant Accession of a new Fire, accelerated together with the Air and the Water of the Interstices, to such a Degree of Violence, that they at last break through the Arch of the Salts, and the Air struck by it, resounds like the Noise of a Cannon.

But without exactly knowing how Fire communicates its Force to the other Elements ; and from the bare Knowledge of the Effects resulting from such or such Mixtures ; Men, by the Assistance of Fire, are able to boil, bake, roast, and dress their Victuals, and to facilitate the Conversion of them into their proper Substance ; to give their Cloaths what Colour they please ; to purify Metals by melting ; to make most magnificent Glasses out of a little Sand by Vitrification : To draw from miry Stones the Cement of Buildings, and a Principle of Fertility from the most barren Lands by Calcination : To reunite with a fat Salt * the smalleſt metallic Particles, which their Separation hindered from being known again : To harden Copper, and make it yellow by a Mixture of some certain Sands † ; to render Metals ductile, soft, and malleable by the Subtleness of the Oils mixt with them ; to neal white Clay, of which, together with a little Sand, they make Utensils, which are most necessary to Mankind : — But in vain should we here enter upon a more particular Enumeration of what we are able to soften, harden, divide, collect, fasten, glaze, and dye, by the Assistance of Fire. Fire is, as it were, the Instrument of all Art, and supplies all our Wants.

It was in order to enable Men always to have at Hand, and prudently to employ this so very precious Substance, that God was not satisfied with placing it only in Air and Water, but has also, and in a special Manner, inclosed it in Fat and Oils. I know not what Oil is : But we all can see, that it is the convenient Magazine, which contains that so very dreadful and volatile Element. With its Assistance, we confine the Fire in spite of its Fury : We carry it wherever we please : We at our Will regulate the Quantity and Measure of it ; and however

ungovern-

* The Borax.

† The Lapis Calaminaris.

ungovernable it may seem, yet it is always dependent on us. Besides, God, by submitting Fire, has likewise submitted Light itself to us. Such are the magnificent Presents, with which he favoured us, in placing oily Matters within our Reach. But Man, instead of discerning the Intentions of his Benefactor therein, very often admires only his own Dexterity, in the Use he knows how to make of them.

Here you have an Opportunity to ask me, What can be the inexhaustible Source, whence we receive again these Oils, which to us seem annihilated by Waste? God, together with Water, and Salt, has, from the Beginning, poured into the Hollow of the Sea a Measure of Oil, or Bitumen, which he has proportioned to the Wants of the whole Globe. Fire and Air incessantly raise from thence a certain Quantity of Water, of light Salts, and minute Filaments of Oil. Thence the Rains, Fountains, Rivers, Vegetations, Nutritions, Savours, Odours, and all the Properties of Flowers, Fruits, Barks, Roots, and Woods. This Oil, unperceived in Rain-water, again collects in Plants its attenuated Particles. It acquires quite different Forms and Qualities, from its Union with the Water, the Earth, the several Salts, and the Principle of all Kinds. For Instance, when inclosed and wonderfully diversified in the Ducts or Farinæ of Flowers, it conveys into the Seeds, as into so many Eggs, a primitive Fire, which begins there to put in Motion the Organs, and the nice and delicate Nourishment it there finds already prepared. The Moisture of the Waterings will continue to supply the Plants with Air, and Oil, and all the other necessary Principles: Since a young Tree planted in the Earth, out of which the Fat has been carefully extracted by a Lixivium or Lye, and which was afterwards dried in an Oven, will grow and bear Flowers, Leaves, and Fruits, have Sapours and combustible Particles, without diminishing the Earth it was put in at first, one Ounce; though it has received nothing, but what it drew from the Air, and the Humidity of the Waterings. This is a small Instance of the Art, wherein God has inclosed Fire in the oily Juices, as in so many Boxes or light Sponges, which the Winds transport, and the Water contains, in order to distribute every where those Things, to which we owe all our

our Tools, Victuals, and Drink. These Oils, exhausted and flattened, are impregnated in the Air with a new Fire, and with the Rivers return to the Sea, which collects them, supports a Part of them on its Surface, and exposes them to the Action of the Air, to be raised anew by a perpetual Circulation; so that if we have Reasons to admire the Profusion, with which God has furnished our Reservoirs, we have no less Motives of admiring that Oeconomy, which always employs the same Elements over again, and makes them serve to supply the Wants of all Ages.

The Fire, which comes out of the Oils to make Plants vegetate, is still more precious to us, on Account of its being the very Life of our Bodies. Scripture points out to us, that the Life of the Animal is in the Blood. That Blood is no sooner destitute of Heat, but it loses its Fluidity and Life. The maintaining of the Fire and of the Motion of our Blood, in a Quantity and Degree, of which God alone knows the just Measure, makes the Duration of the animal Life; and it is in order to supply that Blood with Heat always new, and with the Principle of a perpetual Motion, that we incessantly breathe a new Air, from which Fire is inseparable. On the contrary, the Air we expire from our Lungs, comes from them blunt, unelastic, and charged with the needless Humours it carries off from them. It is very easy to conceive, why Men are lost in the Mines for Want of fresh Air, and why we impair our Health, by living, or sleeping, in Places too narrow and too closely shut. The Children of the poor Peasants are fat and lusty, by only feeding on very brown Bread, and a few Milk Meats; while most of the Children of the Wealthy, notwithstanding the nicest Diet, and in spite of Cares and Remedies, are tender, pale, and of a Constitution which gives their Parents frequent Alarms. The Reason of this Difference is very plain. The first always live in the open Air: And it is dispensed to the latter but sparingly, and as if it were noxious. Instead of breathing that free and brisk Air, and full of Spring, in which God has put a just Measure of Fire, and of the Principles suited to the Necessities of our Blood; the Children of the Rich, always shut up and kept in the Shade, breathe only an Air

Air that is uniform, without Spring, insipid, and very often foul, in a narrow Alcove, by the perpetual Discharges of the Breath and Perspiration. What can be the Purport of those Shutters so well closed, and of those Curtains so exactly drawn across each other? Sure the Parents aim at neither poisoning or stifling these Children they are so fond of; but yet that is often the End of it.

When we consider the Uses of Air, one might be apt to think that Air is the Principle of our Life. We say the same of Water, Oil, and Salt. When afterwards we come to the Consideration of Fire, we are apt to look upon it with Preference to the other Elements, as their Mover, and as the true Source of Existence. But none of them singly and in themselves have any Virtue or Use: They have no Power one without another. One animates and inlivens them all: The other moderates and tempers them all: Take but away one single Part of the Machine, and the Whole will immediately be out of Order, and the Universe become of no Use to us. All remains dull and void of Action without Fire: Even Fire itself has but a blind Impetuosity, if it be not governed. All these Pieces have then no Beauty, or any Force or Goodness, but what they receive from that Intelligence which makes them fall in one with another, like the Wheels and Pinions of a Watch; and which makes them regularly play under the Direction of her Laws.

But how pleasing a Reflection is it to see, that God has been thus willing to engage the Affections of Man by constructing, for his Sake, these magnificent Springs, and by permitting him to set them to work, when and in what Manner he thinks agreeable to his Wants! Whatever is on Earth is placed within our Reach; and that Man might enjoy therein a real Sovereignty, God has granted him Leave, at his Will to dispose of the most active of Elements. By Means of Fire, he is Master of them all. Fire, to which every Thing must yield, submits every Thing to Man. For him it dissolves Stones, liquifies Metals, and makes Iron pliant to all his Designs: Man, in short, has the Thunderbolt in his Hands, without being an Usurper; since he with Fire does what-
ever

ever he pleases, whether he be willing to gather or destroy, to maintain his invaded Rights, or only to procure himself an Exercise of Skill or Amusement. He throws down Ramparts, and breaks Iron Gates. Animals fall under our Stroke at great Distances. Very often the whole Firmament sparkles with Fires prepared by our Hands. The whole Atmosphere is shaken: All Nature celebrates our Feasts, and shares in our Rejoicings.

THE
THEORY
OF
FIRE.

DIALOGUE XII.

THE Review of the Services of Heat naturally leads us to the Examination of Heat itself. In what then does it consist? All that we know of it is, that it is a Sensation more or less lively, more or less pleasing or painful, by which God affects us when Fire is present. But, what can Fire be in itself, and how does it act? If the Ground and first Principles of Beings shun our Sight; who will undertake to dive into the Nature of Fire? It gets loose, and pervades the Instruments with which we endeavour to lay hold of it, and neither the Eye nor the Hand can bear its Approach. Let us go about this Inquiry with Caution. Let us behold it at a reasonable Distance, and be contented with the little we can know of it with Certainty. We shall afterwards pass on to what is but conjectural; that the very Uncertainty of these our Suspicions may convince more and more, that God has spread the darkest Clouds over his Works, though he has made us very clear-sighted

fighted with regard to his Favours; and that true Philosophy does not so much consist in profound Learning, as in a lively Gratitude. What seems to me certain concerning Fire, may be reduced to three or four different Heads. 1. Fire does not consist, as modern Philosophers commonly pretend, in a swift Motion of all Kinds of Matter: But it is a real Body; it is an Element very different from all other Elements. 2. It is a Fluid. 3. It is a Fluid prodigiously elastic, and whose Spring may be infinitely augmented. 4. It is a Body which can neither be produced nor destroyed by any natural Cause.

As these Propositions are of great Concern; instead of endeavouring to answer them by abstruse Arguments, which always leave a very great Uncertainty behind them, we shall proceed here no otherwise than according to Experience. Fire is a real Body, quite different from other Bodies.

Fire is a real Body.
We already have seen it every where distributed from one End of the Earth to the other, but more abundant in one Place, less active in another, and manifesting its Presence sometimes in Proportion to its Quantity, sometimes in Proportion to its Acceleration. All such Bodies as may be equally agitated, ought to be equally combustible, were a great Motion and Fire but one and the same Thing. We nevertheless experience the contrary. The same Agitation of the Mill-stone, which grinds Corn without producing the least Sparkle, affords an immense Quantity of them, and will even set the Mill on fire, when the upper Stone rubbing immediately upon the other, the inflexible Surfaces crush the Air intercepted between them, and having no Retreat, it accelerates the Fire residing in this Air, so far as to set every Thing adjacent on fire. Blacksmiths, Fullers, and many other Workmen know, that the Axis of their Engines, and the Wood that supports it, may be heated very soon; and to hinder it from taking fire, they incessantly cool that Axis with a Stream of Water let fall thereon. This Water does not in the least hinder the Swiftness of the Motion, and yet prevents the Fire.

A rapid Motion is then something different from the Fire: It helps it: It accelerates it: But the Water, at the Time that it lets the Swiftness of the Motion subside, entire,

intire, envelopes and absorbs the Fire dispersed in the Wood and the Air, which prevents the Inflammation of each other Matters. The continual fresh Air you drive swiftly over hot Liquors, cools it only because it contains less Fire than that Liquid, and robs it of a Part of its own. Fire is then a real Body, and not all Kinds of Matter agitated.

Cold Fermen- Motion is so very different from Fire, tations. that some salt Vapours, mixed together and agitated, lose a Part of the Fire which they contained, or become palpably colder. We may convince ourselves of this with a Couple of Thermometers, one of which being dipt into the Liquor, by sinking, shews that the Fire gets loose from it, whilst the other offered at Top, and at the Rising of the Exhalation, mounts, and by its Dilatation shews the Fire which insinuates into its Pores, and which the Motion of the Liquors has dispelled.

On the contrary, you will find other Matters, wherein Fire lodges in so great a Quantity (though every one of its Particles be imprisoned there) that the least Motion is sufficient to break the Chains of many, and set them at Liberty.

The Boulogne- For Instance, the Boulogne-stone, and stone. some other Marcasites, filed, covered over with their own Dust, and then put into the Fire among Coals well kindled, retain in their Pores so great a Quantity of Particles of Fire, that if the Marcasite feels no other Impression than that of the Day-light, when it is taken out of the Cotton wherein it was kept, yet it seems sparkling. That little internal Motion, which Light communicates therein to the first Particles of Fire it meets with, awakes them from their Lethargy, or rather communicates to them an Acceleration that gives that Stone all the Brightness of a burning Coal.

The Phospho- All Phosphores, I mean those Bodies rus. which become luminous, being filled with the Matter of Fire in which they have been put at several Times, are a Proof of this. Different Flesh, Blood, Hair, Shells, Horns, Meal, and an infinite Number of other Matters proceeding from Plants and Animals, but more particularly Urines, are fit to make Phosphorus. We easily penetrate them with a Fire sometimes very brisk, and

and sometimes so very weak, that it causes no sensible Heat at all, and very likely is detained by the Salt which surrounds it. The Spirit of Nitre, and Chalk, are able to produce a very fine Phosphorus *. A little Allum and clarified Honey are sufficient to yield one of the most convenient: For, without offending the Smell in the Operation, it may afterwards be preserved five or six Months together in a Phial well corked; and a Grain of it thrown on Tinder will be enough to enable you to light a Candle. A Grain of *English* Phosphorus †, which they preserve in a Phial full of Water, to prevent the Dissipation of the Fire, being put between two Papers, if you force your Nail over it to crush it, your Papers will immediately take fire. Take a small Piece of the same Phosphorus, and write with it whatever you please on a white Paper, the Letters will not be seen: At most a little Smoke will rise from it and give you the slightest Glimpse of them: But the single Shock of the small Particles of Air, which strike against the Fire contained in those light Strokes, is sufficient to enliven it so far as to be extremely bright. There is no need of a Candle to read a Letter written that Way. It carries its Light with it; but we must be in the Dark to make use of it. There all the Characters will appear luminous, and be the more sensible, in Proportion as the Obscurity is greater, and as you will see nothing but them. This magnificent Phosphorus, the Composition of which is no Secret, and which till now was but a Curiosity, might be rendered of Use. We might employ it to explain our Minds from one Ship to another, while it is dark, or to give Notice of the Wants of a besieged Place, to those with whom we should have agreed about the Signification of some certain Characters. But the Use of the Phosphorus is not here the Object of our Inquiries. It is enough for us to observe, that the Manner in which it is composed, aims at nothing but to drench, or, as it were, to satiate it with the Matter of Fire; and that the Care we take to preserve it in Water is grounded on this, *viz.* because the Water efficaciously detains the Salt, which is itself the strongest Prison of Fire.

Vol. IV.

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* The *History of the Academy of Sciences*, 1711, 1714, 1730, &c.

† Invented by Mr. Kunkel, Chemist to the Elector of Saxony.

It is because Fire is a Body, and an extremely fine and subtle Body too, that it easily gets loose through the Pores of a hard Body, and is stopped by the small Surfaces of one Body that bears some Proportion with regard to its Fineness and Tenuity. A Bottle of hot Water sooner grows cold in a Marble Vessel than in the open Air, and its Fire, which flows off into the Marble and the Air, is preserved a long Time when wrapt up in Stuffs or in Wool; because the Strata of Air, which resist it, are then as much multiplied as the Fibres of the Wool which stop that Air, and the Resistances are multiplied as much as the Surfaces. Fire alone would easily go through each Thread: But it is detained or intangled a longer Time in the Air, with regard to which these Threads are so many impenetrable Textures.

Fire is so truly a real Body, that it dilates all the Bodies it enters into. An Iron Bar, made red hot, becomes a little longer and broader than before. The Iron Gage or Measure which serves as the Standard in some Courts, or in public Markets, does not always agree with itself: It lengthens half a Line, or even more in Summer-time, and shortens in the severest Colds. The Pendulum of Clocks lengthens a small Matter towards the Aequator; which concurring with the slight Diminution of the Weight in those Places, obliges its Inhabitants to shorten the Pendulum; that it may beat true, and not too slow. Watch-makers and other Workmen very often observe, that a Piece of Metal loses its just Measure, and lengthens a little in great Heats. A Pivot too exact, and which too closely fills the Cavity it turns in, may, when it grows hot, so dilate as to retard the Watch by the Increase of the Friction.

What, besides the Infiltration of the Matter of Fire, could widen the Bottle of a Thermometer, and swell the Liquor within it? The Approach of a Wax candle, your Breath, or your Hand, conveys the Fire, which flows from thence, into the Pores of the Bottle which contains the Spirit of Wine. You first see the Liquor contract and sink; because the Belly of the Bottle, somewhat dilated, gives the Liquor more Room: But the Fire, immediately passing into the Liquor itself, makes it rise very sensibly; because it increases the Bulk of it. Here is an Instance still more convincing.

* If a Plate of Steel has on the Side of one of its Extremities small Teeth like a Saw, and those Teeth fall into a Pinion that sets several Wheels a going, the latter of which supports an Index, when you present the Flame of two Wax candles to the Plate, it will so effectually stretch out and lengthen by the Insinuation of the Matter of Fire, that it will set some of its small Teeth a going, and by a necessary Consequence will make the Pinion and the Hand turn: And if there be several Wheels that fall into other Pinions, the Motion of the last shall be extremely sensible. When the Lamina cools by the Efflux of the Fire, it will necessarily shorten, and make both the Pinion and the Hand play the contrary Way. To these palpable Proofs, which demonstrate the Presence of a real Body, let us add those which are drawn from its Properties. The more we know of the Properties, which characterizes it, the less shall we be tempted to mistake it from the bare Motion of the Part of any Body whatever.

Fire is a Fluid, and its Tendency to-
wards spreading every where and every Way is an Effect of its Fluidity. It is be-
cause Fire is a very penetrating Fluid, that it always en-
deavours to be every where on a Level, or in a State of
Equilibrium. A hot Body, that is, a Body full of fiery
Matter, being applied to cold Bodies, such as Steel or
Marble, communicates its Fire to them. A hot Marble
being brought near another, less hot, we by Degrees
experience them to be of a perfectly equal Heat: But
as much Heat as the second Marble acquires by that
Contact, so much Heat does the first lose. The Fire,
by insinuating itself into Bodies, does then endeavour
to spread therein, in an equal Quantity on all Sides, and
thereby manifests its Fluidity to us. We may easily ob-
serve this in the Care we take to pour, from one Vessel
into another, Liquors we have a Mind to cool, by the
Efflux of the Fire into the Substance of a Vessel less warm
than that we empty. It is still more obvious in the tem-
pering of hot Metals. If we dip into cold Water the
End of an Iron Bar made red hot in the Fire, Part of
that Fire flows into the Water, which contains a less
Quantity of it than the Iron: It dilates the Water, and

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makes

* An Experiment of Dr. Desaguliers, F. R. S. of London.

makes it bubble and boil: The Out-sides of the Iron, left by the Fire, contract by the violent Shocks of the raging Water which compress them, and become harder than they were before. So that the Fire, which remains within the Thickness of the Bar, has no longer the same Liberty to spread and flow towards the End and the Sides; because they are both contracted and hardened; but above all, because it finds too many Obstacles in the Water violently heated, and full of another Fire, which repels it. The Fire then finding less Resistance in the Mass and Length of the Bar, than in the Out-sides of the tempered End; it soon recedes from it: It creeps to the opposite Extremity, and the Bar, hot as it was in the Hand of the Workman, when he made the End of it red-hot, ceases to burn, the Moment it is tempered.

When I say, that Fire penetrates Bodies after the Manner of Fluids, and that it spreads in an Equilibrium, I mean, that it begins by doing there at least what Water does when it enters Sand. It does not penetrate the Masses of that Sand, but it lodges itself between the Interstices which separate them; and when it is either abundant or agitated, it may possibly raise the Grains of Sand, and carry them with it a good Way, as if they also were become fluid. Thus it is, that common and moderate Fire heats all such solid Bodies as Iron, Wood, and Stone are: It enters them without displacing the little Masses between which it enters; and when it rushes into them with a greater Force, and in a greater Quantity, it dissipates, melts, and calcines; which in Effect is still more than disuniting and carrying off.

Fire has the same Effect on such Bodies, as are, from the Fineness or Roundness of their Particles, apt to be disunited, and with it to form a more or less dense Fluid. By its Fluidity it dissolves Salt, melts Ice, softens Wax, makes Oil flow, and hinders Liquors from hardening: It communicates to them its own Fluidity, by keeping them in a State of Disunion, and by spreading, not indeed in the very Heart, but in the Interstices of their Moleculæ or little Masses. When Fire has Activity enough to get from between the Interstices into the very Moleculæ of some Fluids, as of Wax, Tallow, Oil, Spirit of Wine, or melted Brimstone; there it finds, as in so many Cells or

small

small Purses, hidden Fire, which they had the Power to retain. That secret Fire, joined with the external, acquires a prodigious Force. They are two Fires which unite their Power; and then it is, that the Inflammation becomes considerable.

This Fluidity of Fire affords us an easy Means to account, how a Liquor, so full of Fire as Wine is, may nevertheless be cooled to such a Degree, as to appear to us as cold as Ice. The secret Fire, which together with some other Principles makes up the Quantity and Strength of the Liquor, is therein tempered and strictly bound or restrained by these Principles. It is as it were shut up and inclosed in Cases, which are able to bridle or contain it in spite of its Activity. This essential Fire is not in the Interstices of the Wine, but in the Heart itself of the little Masses that compose it. And when the Liquor seems cool, notwithstanding that internal Fire, it is because the Air of the Cellar, containing less Fire than the outward Air, sheds a less Quantity of it through the Pores of the Glass into the Interstices of the Liquor. If the same Wine afterwards grows hot in the Air, it is because the Fire of the Air is a Fluid which has a Tendency to enter into whatever is offered to it: And that heated Bottle shall cool again in cold Water; because the Fluid of the Fire, which is in the Interstices of the little Masses of the Wine, will not fail to spread, if possible, out of the Bottle, and get into the Water which is presented to it. Now, that Quantity of Fire, which is freely distributed in so great a Bulk of Water, came from the Bottle. Wherefore the Liquor must then be much cooler than our Air, and our Blood: That Drink will then, when it enters the Body, be very fit to be filled with the too abundant Fire which troubles and inflames the Blood. It causes therein a Contraction, which, if moderate, cannot but be wholesome. Were it excessive, it wou'd rob the Blood of the greatest Part of the Fire which makes it fluid: It would coagulate it, and choak up the Vessels.

When we have our Hand very cold, and apply it to the Heart, the latter does then feel a Cold which contracts it; because the Matter of Fire that Moment abundantly flows from our Blood, and spreads in the Hand more easily than in our Cloaths, which contain and stop a

great Quantity of Air and Fire between their Threads ; whereas the Hand, void of that Element, opens all its Pores to it.

Ice likewise is very fit to cool Wine, because it contains scarce any Fire at all : I say, scarce any ; for it is not wholly destitute of it, since it evaporates, and in Times lessens its Weight ; which would not happen, did not the Fire carry off a few Particles of Water from it. Therefore Ice cools the Wine, not indeed by communicating to it Cold, which is nothing ; but by robbing it of a great Part of the Fire which lodges in the Pores of the Wine, and which the Water does then receive into its own. It is on the Fluidity and Transfusion of Fire, that the Wholesomness of cool Oysters, of Radishes, Sallads, and Baths is founded. The Water of the Bath, and these Foods, as they contain but very little Fire, the more eagerly absorb that which devours us ; whence proceeds that sudden Sedateness of the Blood, which we experience almost equally from the Use of fresh Oysters and that of Bathing. As Physics and Nature concur to inform us of the Necessity of cooling our ordinary Drinks, in order to absorb a Part of the Fire which heats our Blood ; instead of Ice, which is not always to be found, or the Use of which agrees not with all Stomachs, and which is destroyed by the very Use we make of it, we may employ several Salts, which being thrown into the cooling Cistern, make the Water almost as cold as Ice itself, by compressing between their Laminæ what Fire they find in the Water, and thus occasioning the Efflux of the Fire out of the Bottle. We may receive the same Benefit from the Sea Salt, and better still from the Sal Ammoniac. As both these Salts may be crystallized at the Bottom of the Vessel, by the Evaporation of the Water, their Services may be repeated several Times ; so that the Expence is not greater than that of the Ice. The Salt which is extracted from the Sea-weed, being almost of the Nature of the Marine Salt, and extremely cheap, may supply the Place of all the rest. It is a common Saying, that extinguished Coals, or a few Bits of Brimstone dipt into the Water, will cool it. It is said so indeed ; but Experience shews us the contrary. The

Coals

Coals taken out of a Cellar might perhaps have some Effect that Way; but that is a very sorry Shift.

No doubt you would be glad to conceive, how the Dissolution of Salt can render a Liquor colder. The most satisfactory Account I can give you upon that Head is, that Water, having no other Action and Fluidity but what it receives from the Fire spreading in its Pores, so soon as that Action shall begin to communicate itself to the Salts, and reduce them also into a Liquor, the Water necessarily loses by their Division. It loses the more, because it is the Property of Salt to imprison Fire closely, and, as it were, to chain it up: And the Ground of this is, that the little Laminæ of Salt are more impenetrable by Fire than any other Element. The Loss, which Water suffers of that Fire which is dispersed and captivated between the Laminæ of Salt, is so great, that it oftentimes is followed by a perfect Congelation. Nay, a Handful of Salt and Snow mixed together, and applied on the Outside of a Bottle, is sufficient to rob the Water it contains of all its Fire, and to imprison it so far as to make the Water of the Bottle freeze, even in the Middle of the Summer.

The Cooling of Liquor leads us naturally enough to a Consideration into the Fluidity of Fire, for an Answer that may satisfy to the Question you have so often

The Origin of the Signs of Coolness.

heard made at Table: What is that Cloud which cold Wine always spreads on the Glass as soon as it is poured into it, and which brings upon the Servants Reproaches, useful perhaps, but oftentimes undeserved? It is the Cold of the Liquor, say they, which thickens the ambient Air and turns it into Water. But how is that conceivable? If Cold is nothing, it can produce nothing: Besides, Air is constantly Air; and all judicious Chemists agree, that Water never changes its Nature.

Fire alone operates every Thing here either by its Presence or Retreat. The Wine drawn out of a cool Cellar, evidently contains much less Fire than the external Air heated by the Sun. The Fire, of which the Air is full, by an Effect of its Fluidity strives to get Admission into every Place. It then enters through the Pores of the Bottle, and spreads in the Liquor, till it is there in

a perfect Equilibrium, or in the same Quantity as it is in the Air. But we saw in another Place, that the Air is at any Time, and especially in the Summer, full of evaporated and attenuated Particles of Water, which the Fire sustains there, and which cannot be admitted where Fire is. So soon as the Fire insinuates itself into the Bottle, the Air, and especially the Water, which the Activity of the Fire sustained, are abandoned by it at the Entrances of the Passages; where they immediately thicken as a Fog, and afterwards gather into a Mass, which gutters down in small Torrents on the Sides of the Bottle. The same Thing happens on the Outsides of the Glass into which cool Liquor is suddenly poured. Let it be either Wine or Water, the Effect is equally the same; because it proceeds, not indeed from any Fire essential to the Liquor, or from any Quality inherent therein, but from the Equilibrium of the external Fire, which spreads wherever it finds a free Place, which goes backwards and forwards into the Pores of the Glass, and of the Liquor, and which, by insinuating itself from the Air into these Vessels, lets those Particles of Water, which it volatilized, fall on the Outsides of the Glass. If you empty your Glass of the cool Liquor, then a Cloud of Moisture is formed within, as well as on the Outside of the Glass; because all, or nearly all, the Fire that was in the Substance of the Glass, having flown into the cool Liquor, this is no sooner removed, but the Fire of the Air enters into the Thickness of the Glass on both Sides at once. But as soon as the Fire of the Air shall have put itself in an Equilibrium, both in the Air and the Bottle, or the Glass, you will no longer see any Thing of this Kind. When the Fire ceases to enter into them, there is no longer any Fire which abandons the aerial Water, which of course ceases together. Let us trace this Mechanism, and the natural Effects of the Fluidity of Fire; in order, from this Inquiry, to find out the Solution of several Questions wanting Explication.

It is commonly said, that Marble, The Origin of the Moistness of Marbles, Pavements, &c. Chalk, and square Dutch Tiles, attract Moisture. Having here Recourse to Attraction, would be discoursing in a learned Strain on what we should not understand. These Matters do not attract, but only stop the Water.

Water. They yield a free Passage to the Fire, which they refuse to the Water divided by it. Whenever there is in the Air of an Apartment more Fire than in the Walls, that Fire endeavours to spread every where in an equal Quantity. Now, it cannot enter the narrow Pores of the Marble, Chalk, and glazed Earth, without leaving a thousand Particles of Water at the Entrance of the Passages, which are too small to admit them. This Water will gather there so far, as to form a sensible Covering of Moisture. The Fire penetrates, and gets away; but the Moisture remains. It afterwards evaporates from off the Walls. Another Covering succeeds it, and takes the same Course. These Vapours removing from the Walls, swim in the Apartment, just as we see them roll in the Air-pump, after the Air which kept them rarefied has been exhausted. They make the Air thick: They even may render it pernicious to Health when they are over abundant; and still more so, when they mix it with the Salt-petre which they carry off with them from the Foot of the Walls, whither it is sent and extracted from the Urines which penetrate the Earth; which never happens in an Apartment built on a Stone Arch. Tapestry Hangings, on the contrary, hairy Stuffs, Fleeces, Skins dressed with their Hair on, and even the Wood of Wainscots, of inlaid or plain Floors, as they contain in their Fibres, and in their wider Pores, a very great Quantity of Air, the Fire which is in Equilibrio in the Air of the Room and in that of those Fibres, cannot flow into it with the same Liberty, and meets in that Multitude of small Particles of Air and Surfaces a greater Number of Obstacles to its Passage, than in the narrower Pores of the Marble. Among Woods, the most compact, as Box, always is colder than the most porous, as Cork, which retains a great deal of Air and Fire in its Pores.

The same Fluidity of Fire most sensibly discovers itself, in very cold Weather, the Hoar-frost, on the Glass Windows of our Apartments.

Fire, inclosed in the Air of a Room, necessarily spreads on every Side, if it be fluid. It must needs endeavour to get loose; and plant itself wherever there is the least Quantity of the same Element, and it will make no Effort to flow into an Air already as hot as that it is possessed

fessed of. It will therefore be stopt by the Wood, and more so still by the Tapestry Hangings, which contain a great deal of Air. On the contrary, it will flow off through the most compact Texture of the Glass Windows, which contain neither Fire nor Water. It will disperse in the colder Mass of the external Air, till there is an Equilibrium both in the external Air and that of the Room. The Fire, which goes out through the Window, leaves within, and at the Entrance of the Pores, the Particles of Water and Air to which it was united. These form a Cloud, which grows denser in Proportion as the Fire goes out. At last the Quantity of Fire, which by little and little flows into the cold Air without, is so great, and that, which remains in the Mass of Air within the Room, becomes so very small, that it can no longer keep the Particles of Water, which are condensed on the Glass Window, in a State of Fluidity. That Water must then of Necessity freeze: And in Reality all the Particles of them fall one on the other by small Parcels or by Filaments, much of the Nature of Snow, forming at Random some seeming Foliages, according as their Weight, or the Impression of the Air, has driven them to the Right or Left, and they are drawn near to each other in the Congelation. This is what we call a Hoar-frost or Rime, which, as you see, must be, and in Reality is formed on the Side of the Glass Windows next the Apartment. But as soon as the external Air shall acquire a greater Heat than within the House, by endeavouring to spread from without in the Room, then the Moisture will appear on the Glass Windows without: A Thing we constantly experience in every Thaw. In Consequence of the same Fluidity of Fire, when the Air, which has been a long while cold in large Halls, shall begin to become warm again, and the Fire penetrate in greater Quantity the Columns of Stone, the Marble, and the Pictures; then the Moisture shall hang on the Outside of them, and flow down them in Streams.

From the same Cause proceeds the Thickening of our Breath, so far as to be sensible when the Weather becomes cold and cloudy. The Efflux of the Fire from our Breath into the external Air, lets the moist Particles of it fall one upon another; and they are the more sensible,

sible, when they meet in the Air with some others which are an Obstacle to them.

The Thickening of our Breath on a Marble, a Glass, or any other very compact Body; the Re-union which is made of the Vapours of boiling Water under the Cover that stops them; the Condensation of the Fumes of an Alembic, when they adhere to the Top, and contract in a Pipe surrounded with cold Water; the gathering of the Dew on Glass or Marble, rather than on Cork or Fur, are again so many Operations wholly owing to the Fluidity of Fire, and the Coarseness of the Matters it sustained. This evaporated Matter would meet with a Resistance, and be obliged to undergo a Conflict, did it meet with any Air or Fire lodged in the Pores of Cork, and still more so, if it should meet with a Cover red-hot, and full of another Fire; it would be repelled thereby; but the Fire getting quietly loose through the smallest Pores of cold Marble, a Glass, a Piece of Slate, or of Glass destitute of Heat and Air, there quits the Company of the watery Particles, which prove too gross for so narrow a Passage: These Particles stick thereto, without being able to proceed any farther. The Body that stops them is properly a very fine Sieve, which gives Passage only to the Fire. Everybody knows, that cold Meat hardens, when you warm it again in Water; and that on the contrary, you may warm it without making it either hard or insipid, by putting it into an earthen Pan well covered, and placed over an earthen or cast Iron Pot, in which Water is actually boiling, called the vaporous Bath. The Fire incessantly raises from the boiling Liquor Bubbles of Air and Water, which spread all round the earthen Pan. The Fire which penetrates the Pores of it, gently warms the Meat already prepared: But the Water it quits, condenses under the earthen Pan, and thence gutters down in large Drops.

Let us proceed, and run over some other Experiments, to prove the Fluidity of Fire, and its Tendency towards putting itself on a Level, and in Equilibrio, wherever it can get Admittance. It is in order to shelter us from the Efforts of the Fire residing in the external Air, and which is always ready to spread every where, that we in Summer-time oppose its Passage by Curtains and Windows;

dow-shutters. What we get by this is not to free ourselves of it intirely, but to experience much less of it, and to breathe an Air colder than the Humours of our Body.

* It is because Fire, notwithstanding all our Caution, gets into our Apartments, that it insinuates itself to the very Bottom of our Cellars. Though they seem to us then to be very cool, they in Reality contain more Fire than they did in the Winter, when they appeared warm to us; since the Thermometer was then lower in it than in the Summer: And these Appearances, which seem contrary to Truth, convince us, if we do but consider, that God has regulated the Order of our Sensations, and the Notices he gives us of what passes without, not on the State of Things themselves, but on the Importance or Concern they may be of to us, and purely as they relate to ourselves. We then in the Summer perceive the Air of the Cellar, or of a Marble Hall, very cool, not that it is then void of Fire, or that it contains less of it, than in Winter; but because that Fire being much weaker than that of the external Air, which scorches us, we are informed by the agreeable Coolness that is perceived in low Places, or in the Liquors drawn out of them, that we have found a sure Means of freeing ourselves of a great Part of that excessive Fire which dilates and disorders the Humours of our Body. And the Air of the Cellar, on the contrary, seems to us hot in Winter, not that it then contains as much Fire as in Summer-time, but because it contains a greater Quantity of it than that which actually floats in the external Air, which affects our Body, and may occasion too great a Loss. This Variety of Appearances is perfectly like that which we experience, when having one Hand very cold, and the other very hot, we dip them both into lukewarm Water. The Water shall seem very warm to the cold Hand, into which it insinuates its Fire; and very cold, on the contrary, to the warm Hand, which it robs of its own.

The Elasticity of Fire. Having proved the Fluidity of Fire, we have already proved its Elasticity, or its natural Disposition to spreading, and every

* Whether Cellars and Vaults are indeed warm in Winter, and cold in Summer.

every Way pushing against what surrounds it, with this Difference between it and the other Fluids, that Fluidity and Elasticity are inherent and proper to it, whereas others do perhaps receive that Activity from it. A Crowd of other Proofs, which we daily have before our Eyes, more than sufficiently convince us, that Fire incessantly strives to make itself a Passage every where, to dilate on all Sides, to spread all round, to proceed, to penetrate, to dissipate. Is there any Thing that it cannot go through or dissolve? But this so powerful Elasticity does not always act in the same Manner. There are even Cases in which it is no longer sensible, even in a very great Fire. We very often see the Fire rolling on itself, and without Fewel in luted Vessels, quietly getting loose out of them, and to Appearance making no Manner of Effort to break them. If the Strength is always the same, whence can this Diversity proceed?

There are in Nature but three truly fluid Bodies known, and which by their perpetual Activity are the Principles of all Motion. I mean Light, Fire, and Air. The Light is an universal Fluid, which extends to the very Stars; our Fire and our Air are two Fluids attached to the Earth for the Service of Man, and spread round his Habitation. The Light is of such prodigious Fineness, that it pervades the Textures of all Bodies, and influences them only by Help of Fire, with which it is in an exact Proportion. It impels the Fire, and is thereby reciprocally repelled. It renders Fire more active, by communicating its Motion to it; and Fire troubled or forced out of its Equilibrium, reciprocally acts upon Light, and makes it shine. But the Body of Fire, though heavier than Light, is yet too fine to be able of itself to displace the Masses of terrestrial Bodies. It crosses, without disuniting them: It gradually flows from, without breaking them. It every where finds Passages free enough to get loose, without making any Fracture. But by the Shape of its Particles it keeps an exact Medium between the Light and the Air. And as Air is a heavier Fluid than Fire, its Union with the Air makes it already more capable of acting upon those Bodies it would only have grazed upon, or have penetrated without Opposition. Fire, in itself full of Activity, borrows a double Acceleration, and consequently

a double Force, both from the Impulse of the Light, and the Spring of the Air let loose against it.

Fire borrows many powerful Helps, besides, from other Fluids, such as Oil, Mercury, Salt, and Water: But it is assisted by them in a very different Manner. These Elements have only a borrowed Fluidity. They are elastic, or inclined to dilate only in Proportion to the Quantity of Fire they receive into their Pores; since they coagulate or freeze by the Efflux of Fire. When they are added to the Fire, they properly add nothing to its Quickness: But it is not to be imagined, how much they contribute to render its Action terrible, and full of Force. The Oil supplies the Fire it is thrown into with another very plentiful Fire, and a Multitude of Bubbles of Air is confined in its little Masses. The Consequences of it are easily observed. Oil is the true Jewel of Fire. Mercury, Salt, and Water, may imprison and surround the Fire, and render it of no Force: But if that Fire comes to increase its Quantity and Velocity, it is then the more dreadful, because it acts in Concert with those Elements, and drives before it Masses capable of barring its Passage, and which will help it to overthrow every Thing; whereas without the Opposition of their Surfaces, the Fire would be dispersed through a greater Space, or flow out through a greater Number of Pores, and thus remain without Effect. It is the Proportion of the elementary Parts which makes this Variety in the Effects of the same Power. Throw the smallest Flint into a great Fire, the Fire and Air, which incompsas the Surface of it, have not Power enough to throw you that Mass back. Do but pour Water into a great Fire; the Proportion between the little Masses of Water and those of the Air animated by the Fire is such, that the Water, in itself without Activity and Resistance, shall on a sudden be repelled with a prodigious Force and Degree of Expansion. It hurries away with it Ashes, Coals, Shards of Pots, Bricks, Stones, and whatever it meets with, and oftentimes produces very sad Accidents in Kitchens.

The Fire and the Air, which exhale from Hay or from Sheafs of Corn newly put together in a Rick, are dissipated without any Damage, if the whole be well dried. But if the Heap be moist, the Fire and the Air

Air stopp'd by that Moisture, heat it so far as to penetrate, and rot, and even sometimes so far as to fire the Rick. The Farmer may prevent this Mischief. When rainy Seasons force him to house his Harvest without an Opportunity of drying it, he places in the Middle of the Rick, two or three large Faggots of Thorns, and by that Means leaves a large Space, to which the Fire and Exhalations coming from all Sides, dilate, and thus lose all their Force, and Activity.

We shall find the Proofs of a like Mechanism in the Eolipyle. It is a small Vessel of Brass of the Form of a Pear, having towards its Point a small crooked Pipe, with an Orifice of about the twentieth Part of a Line. When this Vessel is put on a very quick Fire, the Fire will dilate the Air within: It will go backwards and forwards through the Pores of the Pear, without any sensible Alteration; because the Air it drives away finds a Vent through the Orifice of the Pipe. If that Pear, being red-hot, be dipped into the Water, the dilated Air therein contracts on the Approach of the Water. The Vessel by Degrees is filled with Water and Air by pretty near equal Portions. Now, again, put the Eolipyle on the Coals, with the small End of it dipping towards the Fire, and the Orifice of the Gullet turned upwards, which by this Means the Water fills without flowing out: So soon as the Fire is clear, that Element, which seemed not to act on the Inside of the Pear when it was without Water, and nothing to confine it, begins by dilating the Air there: The Air unbends all its Springs, against the Water which surrounds it: This, though by Nature void of Activity, being strongly pushed every Way, and at the same Time confined by the Sides of the Vessel, finds no other Issue but the small Vent of the Gullet, towards which all the Fury of the Fire and the Air, and of Course that of the Water, turns and centers. The Water gushes out of it, notwithstanding the Smallness of the Vent, and the Resistance of the external Air, and rushes forward to the Distance of fifteen or twenty Feet. In this Manner Fire, which burns, and is kept quiet under a Heap of Ashes, by the Liberty which a thousand little Passages leave it of getting out into the Air, and of borrowing some Assistance from it: That Fire, I say, when it receives

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receives a few Drops of Water round it, dilates them, lifts them up, and with them the Coals and Cinders. For this Reason it is, that subterranean Fire, which, if alone, would roll round or through a small Flint without displacing it, being joined to the Air and Water, lifts enormous Masses, shakes whole Regions, pierces the Ground, makes Rocks mount into the Air, and overthrows whole Mountains. A Simile will make this sufficiently clear.

A Crowd of Boys see at a Distance some ripe Fruit. To see and covet them, is with them one and the same Thing: They first of all survey all round about: No body appears to molest them: Nothing but a Hedge parts them from the Object of their Desires: How is this Barrier to be got over? In vain do they apply their Hands and Sticks to the Hedge: The Sticks go through: Their Hands are scratched: Tears flow: Nothing has as yet been removed. They perceive a Harrow raised against the Hedge; and by the Advice of the best Genius among them, they all in Concert apply their Sticks against the Bars that join the Pieces of the Harrow. They work so hard with their Feet, their Arms, and the whole Weight of their Bodies bearing against the Sticks, that all these little Forces united, which were of no Effect when they could act but a single Point, now pushing against the Hedge by the whole Breadth of the Harrow all at once, they make a Breach in the Hedge, and plunder without Controul.

The Harrow gives these Children no Manner of Strength, but it unites and improves those Forces, which by being disunited were rendered of no Effect. So when the Fire, assisted by the Air, drives before it Surfaces of hard or massy Elements, such as Salt and Water, which cannot be admitted through the Apertures that would yield a Passage to the Fire, then does it make the most horrid and dreadful Havock, and overthrows, bruises, or scatters, by that Means, what it would have singly gone through, by a steady Efflux, and without damaging any Thing.

Therefore, though the Elasticity of Fire be not always sensible, yet it is always effective, and it is from that Elasticity modified or assisted by the other Elements, that we may deduce the several Actions of Fire. Let us collect all we said about it, and form a Sort of Dictionary of it,

it, that may the better unravel the whole, and fix it in our Memory. The Actions of Fire are to kindle, to increase, to smoke, to shine, to blaze, to crackle, to sparkle, to ascend, to evaporate, to blacken, to dry, to melt, to vitrify, to calcine, and to be extinguished.

Fire kindles: Not that it takes Birth where it did not exist; but because it gathers and becomes active where it was at Rest, and by a borrowed Help becomes victorious where it was chained up.

Fire increases, either in Quantity or Velocity, or both Ways at once; and that by five principal Means. 1. By the Impulsion of Light, especially when its Rays are collected in one and the same Point, or on the same Parcel of Fire. 2. By the Impulsion of the Springs of the Air, especially when they tend to the same Place. 3. By the Affluence of the Oil and of the Fire contained in fresh Air. 4. By the Junction of the Fires contained in combustible Matters, and especially in oily Juices. 5. By the Narrowness of the Space within which a great Quantity of Fire is confined and accelerated between Surfaces of Water and Salt.

It smokes, by carrying off the Waters and other Particles which it is capable of raising, and among which it is enveloped, being in too little a Quantity to incompass and overpower them, so far as to strike immediately against the Body of the Light. The Smoke is so full of Fire, and it is so very true that the Fire forces it upwards in spite of its Weight, that if you pour Water on a burning Log, you run the Risk of scalding your Hand, in passing it through the Vortex of Smoke that rises from it.

Fire blazes, when it is stopped within a narrow Space by a small Quantity of Particles of Water, taken from the combustible Matters, and is there accelerated by the repeated Shocks of the Springs of the Air. A moderate Moisture, made up of Water and Oil, is properly the Cause of Flame. Therefore Coals, that have lost almost all their Moisture, yield little or no Flame at all; and if the Fire of the Flame is the strongest of Fires, it is because each Particle of Fire being barred by as many Particles of Water, their Vortices become the more rapid, and act the more violently, by the Help of the Surfaces

of the Water, and by dilating less. Would one naturally suppose, that it is this exact Measure of Water inclosed together with the Fire, in all oily Juices, that makes up the Flame of Sulphur, Wax, Tallow, Fat, and Oils? The Analysis, which discovers that Water again in them, leaves us no Room to doubt of the wonderful Providence, which has for our Sake lodged, in the Cells of Oil, Principles so different from one another, and rendered them so very active and powerful, by the exact Proportion of their respective Quantities. But the Water and Fire of the Oils, when disengaged by an external Fire, and all Sorts of Flames in general, acquire a new Degree of Force, when the Air joins them by its Agitation and constant Renewal. We need not, in order to convince ourselves of this, have Recourse to the prodigious Force which a perpetual Blast, always directed to the same Point, gives to the Lamp of an Enameller. The Use of our common Bellows is sufficient to inform us, that Fire, strengthened by the Shocks of the Air towards a small Mass of Fire, spreads through, and in all the Outsides of the Particles of Water, and of other Elements, which it carries off from the combustible Matters, and by shewing itself, hinders them from being seen; whereas that Brightness ceases, when the aqueous Particles are too abundant, and when the Fire, inclosed within the Masses of Smoke it drives away, does no longer act immediately on the Body of the Light.

Smoke is Flame begun, and the one is so little different from the other, that the least Increase, either of the Quantity, or Velocity of the Fire, is sufficient to turn the Smoke into Flame. If you bring a Wax-candle, just put out, near another that is lighted, holding the smoking Snuff a little lower than that on Fire; as soon as the Smoke of the first, carried by the Motion of the Air, shall touch the Flame of the other, the Flame will spread both without and within that Smoke, and creep as it were into it, descending towards the extinguished Match, which it will immediately light again.

Fire *shines* without either Smoke or Blaze, when it finds, in the Body it consumes, few or no aqueous Particles that stop it; so that it flows off, and is more easily dispersed. That Brightness, free from Smoke and Flame,

is obſerved in all combustible Matters, after they are reduced to a Coal by the Diſſipation of their Moiſture.

Flame therefore is properly nothing but a middling Kind of Smoke, on which the Fire prevails, notwithstanding the perpetual Opposition of the Water that stops it. For this Reason it is, that the Fire of a Forge becomes ſo very bright, when after it has been contracted, and damped by the Water of the Wisp, it gets the better, and carries off that Water. For the ſame Reason, when Fire feizes on a Tun of Oil, or ſome other Maſſ of fat or oily Juices, if ſome unexperienced Hand happens to pour Water upon it in order to put it out, the Fire, instead of being thereby abſorbed, divides and overpowers it, with an Expansion or Deflagration extremely bright, and capable of firing every Thing in the Neighbourhood of it.

Fire crackles, when it violently lets loofe ſome Particles of Air imprifoned between Laminæ of Salt. There it does in a leſs Degree, what it does with a great Noiſe in Gunpowder, and in the *Pulvis fulminans*.

It sparkles, when it is ſtrong enough to diſperſe ſome small Parcels of the combustible Matter wherein it is incloſed. Such are the Parcels of pounded Coal it ſucceſſively cauſes to iſſue out of a Squib or Rocket.

Fire rises, or always tends to that Direction. For though it violently ſpreads on all Sides, and gets to the Bottom, as well as the Sides of the Bodies it consumes, when composed of many very elatiſt Vortices, and aſſisted by the Elatiſticity of the Air, it has beſides a natural and ſenſible Tendency to go off from the Earth, let that Tendency be looked upon as the primitive Impreſſion of him who made every Thing as he pleaſed, or as only the Reſult of leſs Heavineſſ; whence it happens that the maſſier Bodies place themſelves below it. However that Effort, which Fire makes to get above, carries along with it the Matters it has diſvided, with all the Air it has either unbent or dilated. The Parcels of Water, of Tallow, of Wax, and the heated Air ſpreadiſg upwards, make a more remote and more contracted Air, which is always charged with a little Water, to return on every Side the Flame. The Spring of it being brisker, that Reflux of Air is the chief Fewel of the

the Fire, both from the Constraint it is retained in, and the perpetual Supply of Water it sustains, and of the Oils which the Water carries every where upon its Globules.

Fire *blackens* what it has not the Force of either consuming or destroying. When it has driven off all the Moisture of a Piece of Wood, it circulates in a thousand Ways through the Texture it cannot divide; and when it is dissipated, the Wood is then pierced with so many Holes, that the Light is therein absorbed, and no Part it is beaten back by Reflexion, but that which is necessary to render the Form of that Body visible, in which the black Colour consists. A learned *Englishman*,

Hook's Micro- mous for his Industry in perfecting Micro-
graphy. scopes, judging of the Quantity of great

Pores, which the Surface of a Coal an Inch in Diameter contained, by the Number he could reckon in the eighteenth Part of an Inch, found, that that Diameter contained above seven Millions seven hundred and eighty Thousand. What must then be the Number of imperceptible Pores, and what a vast Dissipation must the Light suffer in so many Apertures?

Fire *evaporates*, or causes the Moisture it meets with to evaporate. When it has Strength enough to hurry with it the little Masses of Water that oppose its Motion, it fills the Air with them, and disperses them to Distances far superior to the Regions of the Clouds. The whole Interval, from the Top of the Atmosphere down to the Earth, is full of these Bubbles of Water. The Light, the Fire, the Air, and the Water, are evidently one within another, exercise each of them its proper Action, without Damage to each other; and on the contrary work in Concert for the Service of the Earth.

Fire *dries* and hardens all those Bodies, the Moisture of which it evaporates: But it performs this Operation only by the Assistance of the Air. Wherefore a sharp Wind in a Manner dries and burns as Fire does; because by carrying away the Water in its Course, it contributes to draw again near each other, and to harden the Particles of the Surfaces which the Water quits. Frost also hardens, but in a very different Manner. It does it, not by carrying away,

away, but by contracting the Water by the Efflux of Fire. And when this Contraction of the Fluids happens in the Body either of Plants or of Animals, it compresses, disturbs, and breaks there the little Vessels necessary for Nutrition: Whence it happens, that a Leaf, which has been frozen, having no more its Vessels placed as before, rots at the Thaw: And if the Sun shines upon it, and draws off all the Moisture of the rotten Leaf, the Texture of it is totally destroyed, and it is no more than a Quantity of Dust.

Fire makes fluid, or puts into a State of Fusion, Water, Oil, all oily Juices, and generally all Metals. It in some Sort communicates its Nature to them; since it puts them in a State of Fluidity; and its communicating that Quality to them, rather than to the other Bodies, is, because being more simple, and made up of uniform Particles, they are the more proper to retain it in their Interspaces wherein it rolls, displacing these little Masses, and making them tumble one upon another. What confirms this the more is, that when it spreads therein in a greater Quantity, or with greater Violence, it pervades, scatters them, and makes them evaporate. Thus it exalts and refines Salt, Mercury, Lead, and all Metals; since Gold itself, weighty as it is, insensibly is dispersed in a great Fire, and never comes out of it without some Diminution.

Fire *vitrifies* and *calcines*. It vitrifies Sand, and calcines real Earth or Soil. The Diversity of these Operations does not proceed from the Fire, whose Action is always the same, but from the Nature of the Matters on which it acts; and if we see it in the same Mass of Minerals oftentimes discharging the three Functions of melting, calcining, and vitrifying, it is because it at once finds metallic Particles to melt, Sands to vitrify, and Earth to calcine. Fire produces nothing there, but it displays what was in it before, and will never cause Metal to become Earth, or Sand to turn into Ashes, or Ashes to be transmuted into Metal. These Things may be united or separated. One may predominate over the others; and the whole may flux and be carried away with the melted Metal. The Sand may envelope both Earth and Metal in a Vitrification that hides them? But each

See *Boyle, De Ponderabilitate Flammæ.*

each of them invariably keeps its own Nature ; and if in many chemical Operations some certain Matters become much heavier, by passing through the Fire, it is not at all because the Fire or the Air is converted into these Matters, but because they incorporate with them Masses of Water or of Salt, and more particularly oily Juices, with which the Air and combustible Matters are impregnated.

Fire itself, when it *goes out* (and this is the last of its Actions remaining to be explained) is then neither dead nor destroyed. It scatters : It is dispersed : It does no longer act as it did before, but is still what it was in all Respects. Have you a Mind to extinguish it in a burning Log ? You must absorb that Fire by a Quantity of Water superior to it. It is no longer in the Log ; but it wholly subsists in the Water, which it raises into a Fume. Would you extinguish it in a Charcoal-pit, where it burns the Wood abandoned to its Fury under a Heap of Earth, and which it devours by the Assistance of a few Holes, through which it is supplied with Air, in order to renew it and keep it up constantly in the Wood ? You need only stop those Holes, which deprives it of all Correspondence with the Air. As soon as it is destitute of the Company of that gross Element that gave it Strength, and by the Density of which it violently shocked the Texture of the Wood, it immediately penetrates the Mass of Earth, that covered the Coals : It has no more Activity ; because it spreads and gets away without any Return. But it is in its Dispersion the same it was when a continual Flow of fresh Air repels and nourishes it in one and the same Place.

From all these Facts, Sir, which I have thus united before your Eyes, and from an infinite Number of others, which Experience will every Day afford you, results a Truth which I take to be capital in Physicks, as well as in Moral Philosophy ; *viz.* that God has placed between Man and all the Objects around him, such an evident Relation of Usefulness, and Appointment of Services so easy to be discerned, that in the Heaven, as well as on the Earth, the View of Nature is perpetually pointing out to him the tender Regard and Affection of his Creator

tor towards him. Every where between the Heaven and the Earth, between the Light and the Atmosphere, between the Fire, or the other Elements, and Man, we observe the same Unity of Intention, and the same Correspondence, which we remark between our Appetite and our Food, between our Teeth, which grind and fashion our Meats, and the Stomach that digests them. Physics are then an admirable School of Piety; and all the Sciences of any particular Purport may become so many Informations to the Mind; since in the admirable Artifice of each individual Piece, there is nothing which we more evidently discern, than a constant Intention in the Creator of being every Way beneficial to us.

Hitherto we have bestowed our Attention only on what shews itself apparently, and requires no great Penetration to be apprehended and conceived. But this so useful and so affecting Science contains some other Particulars, the Discovery of which must needs have required a great deal of Time and Trouble. Instead of informing you of them in a scholastic Manner, and by abstruse Arguments, let us here borrow the Assistance and Charms of History. Let us from Age to Age trace Men in all their several Wants, and the Works of great Men, in the Endeavours they have made to be of Service to Mankind. Let us, in a Series of historical Dialogues, examine first, what Experience has procured us, on the Certainty of which we may depend: And then what Benefit may be drawn from the Systems of Philosophers. This Method of studying Physics will be more agreeable to you: And I think, whether to confine you to a didactic Order, or suit my Method to your Inclinations, is a Point easily determined.

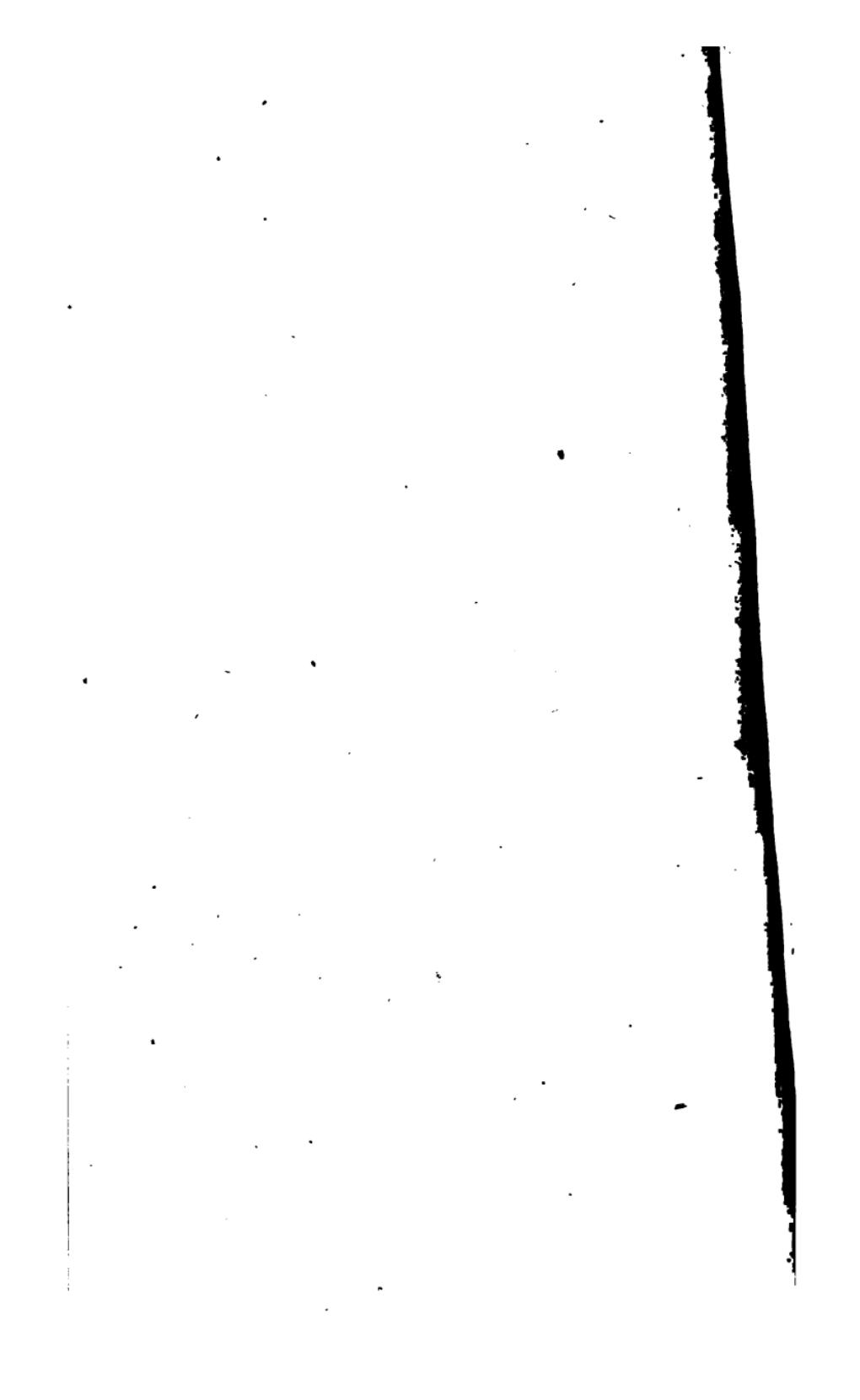
The whole Survey of Nature has already convinced you, that all the Parts which compose it are the Work of a single Intention, which created, united, fitted them, and made them relative and conducive to one and the same End. Let us now see in the History of the Study which Man has made of them, how far the Progress is carried. Let us enrich ourselves with his Labours. This History, by informing us of many particular and practical Truths, may facilitate to us the Clearing and Solution

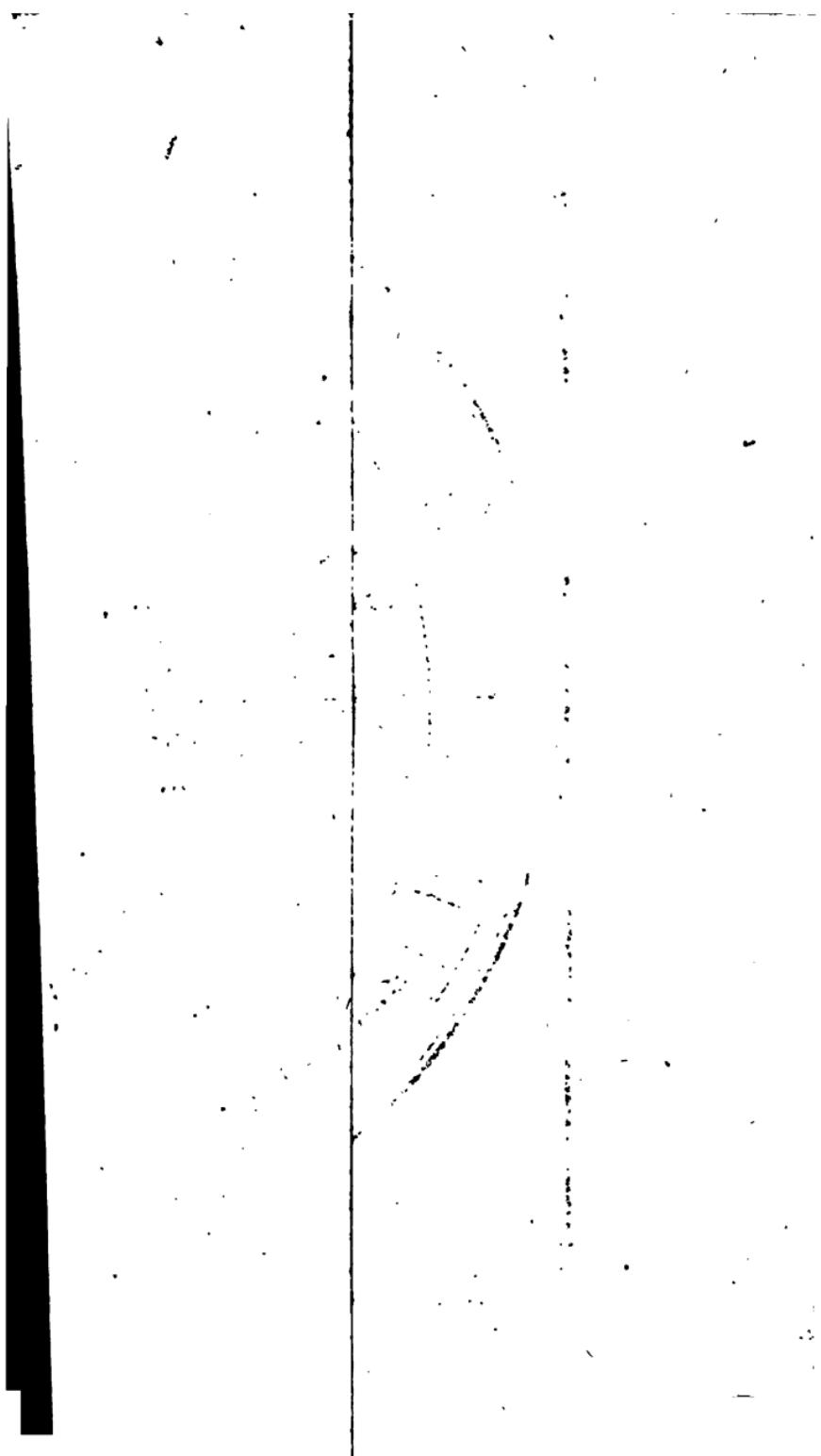
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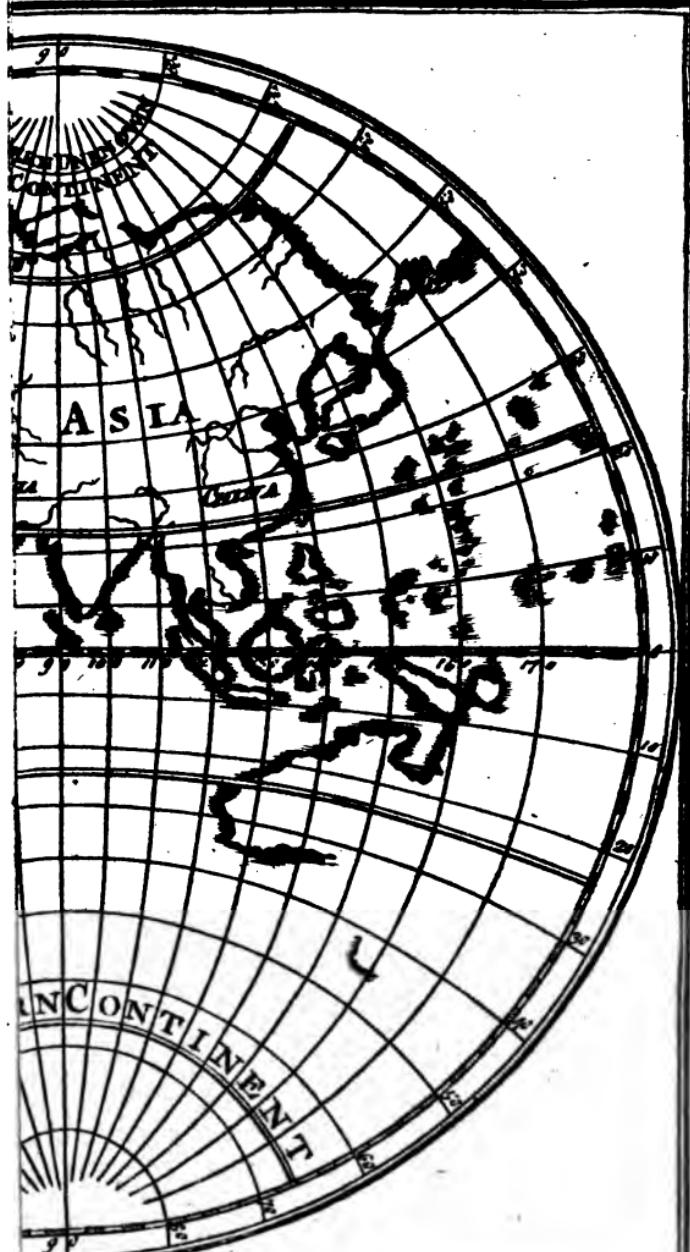
tion of an important Question, *viz.* Whether the Discoveries, made by Men in six thousand Years past, give us any Room to think, that we shall ever arrive at knowing the Ground-work and Nature of what surrounds us; or, that God has granted us no more Light and Knowledge than what is sufficient to rule our Minds, and supply our Hands with proper Employment.

Spectacle de la Nature.

THE
SEQUEL
OF THE
FOURTH VOLUME,
CONTAINING THE
HISTORY
OF
Experimental Physics.







THE
HISTORY
OF
Experimental Physics.

The Invention of the ZODIAC.

DIALOGUE I.

ASTRONOMY, or that Part of Physics employed about regulating the Order of our Days, by the Inspection of the Heavens, as being the most necessary, was also the first cultivated. When Noah's Children had quitted the Rocks of the *Gordyan*, and begun to form a numerous Nation in the wide Plains of *Sbinar*, the Necessity of providing for their Food, and that of their Flocks and Herds, obliged them to separate at some Distance from each other. But though they knew that God had designed them to repeople the Earth, they obstinately resolved to keep all together; and lest they should be obliged to disperse, they began to build a City, and a Tower so very high, that it might be seen at a vast Distance, and serve as a Signal to gather themselves again together*. From that Time

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the

* The Hebrew has it thus: "Let us make a Signal (*Sben*) lest we should be dispersed through every Region." The Word (*Sben*) has produced σῆμα and σημεῖον, which in Greek signify "a Mark, a Sign, or a Name." But those who translated it, "Let us make a Name, let us render our Name famous," were forced to put *Astegnum* instead of (*Psa*) *No forte*, and to translate it in these Words: "Before we be separated on all Sides." Which does

the unavoidable Necessity of ordering the Affairs of Mankind, and of settling the Times for the Operations of Husbandry, obliged them to agree upon some convenient Regulations, and a certain Method of measuring and calculating of Time. They most naturally made Use of the periodical Revolutions which they observed in the Heavens. The Return of the same Motions, and the Renewal of the same Phenomena were insensibly pitched on, as the most fit Terms to fix Expirations, or to mark out the Times of ploughing and sowing, because these Returns were regular, and, besides, obvious to every Eye.

The plainest Measure of Time they The Moon the could employ at first, was that which the first Rule of Moon offered them. By every Day Mankind. changing very sensibly the Place of both its Rising and Setting, by varying its Form from Day to Day, and by beginning afterwards a new Order of Changes, initially like it, it at once became a public Rule, and afforded them an easy Kind of Reckoning. They might date either from the New- or the Full Moon, or from such or such a Quarter. They might join several Quarters together, or as many complete Lunations as they thought fit. Thus, without the Help of Almanacks or Writing, every body could find in the Heavens a Warning or *Memento* of what he had to do. All Families, however remote, gathered together without Mistake at the appointed Term; and instead of measuring Time by a Number of Days, which their Resemblance might confound, or the Series or Sequel of which, once lost, could not be again found, they were exempted from all Inconveniences of that Kind, by referring the short and long Durations to the Course of the Moon, which shewed them from one Day to another; by a new Sign, what Time was already expired from the Beginning of one Term, and what remained till the following.

Men, who lived in the first Ages of the World, affected by the Consideration of the twofold Service the Moon did them, by enlightening the Night, and by regulating the whole Community, consecrated the Use they made of

does not agree with the original Text, nor express the Undertaking, which was directly opposite to God's Purpose, (*viz.*) to re-peopple all the Earth by the Family of *Noah*.

of its Phases by a Holiday or Feast, which they solemnized at every Time of its Renewal. The *Neomenia* served in a plain and commodious Manner to regulate the public Exercise of their Devotion. But if they regularly gathered together to make their Sacrifices, and in a friendly Manner visit each other at the Return of every new Moon, that Worship and those Holidays were no Way relative to the Moon itself. God was the Object of them; and the Moon had no other Share therein, but that of putting Men in Mind of celebrating them.

The Stars had not as yet received the Names they now go by. Without taking Notice of the several Constellations under which the Moon is successively placed within the Space of its Monthly Course, Men were contented with only determining its Progress, by the Variety of its Appearances; and instead of employing Calculations, as has been since done, to mark out the precise Instant of its having again overtaken the Sun, under which it had passed nine and twenty Days before; the Astronomy of those Times was contented with the bare Testimony of the Eyes, and they reckoned the new Moon from the Day it could be perceived. It was in order more easily to discover this, that they assembled in high Places, or in Deserts remote from the Habitations of Men; that no Obstacle or any Thing might screen the Horizon from them. When the Crescent had once been seen, they solemnized the *Neomenia*, or the Sacrifice of the new Moon, which was succeeded by a Repast, where all the Families chearfully, and with Simplicity and Candor, eat what had been offered to God, and consecrated by Prayer. When any notable Event occasioned the Institution of some annual Feast, they very often joined it to the *Neomenia*, which was the usual Day of Assembly. The new Moons, which concurred with the Renewal of Seasons, and to which our four Ember-weeks do still correspond, were the most solemn of all. That Custom of meeting together in high Places or in Deserts, that of keeping the new Phasis, that of celebrating the *Neomenia* by a Sacrifice and by Prayers, in particular, the Solemnity of the new Moon, which concurred with the sowing, or followed the intire Gathering of the Fruits of the Earth; finally, the Repast and

Songs, which came after the Sacrifice, are Usages, which were, from this common Source of Mankind, handed down to all the Nations of the Universe. All these Customs we find again among the *Hebrews* *, the *Egyptians* †, and the *Arabians* ‡, from whom they, together with *Mahometism*, were delivered down to the *Perians* §, and the *Turks* ||. The same Usages were common to the *Greeks* ¶ and the *Romans* **, to our Fore fathers the *Gauls* ||*, and to Nations which had no Manner of Communication with each other: They were found again amongst the *Charybs*, and some other *American* Nations *†.

Scripture abounds with Facts, which evidently prove, that the Custom of sacrificing on high Places was established among the *Hebrews* as well as other Nations, even before the Law, and that it even subsisted in *Israel* since, and in spite of the Law. The Law itself testifies its Antiquity, by forbidding it, as capable of impairing the Unity of the Worship. That of the *Neomenia*, as antient and universal as the other, was preserved and regulated by the Law. The Learned, observing between the *Hebrews* and the *Heathens* so great a Resemblance as to their Sacrifices, their resorting to high

* The Request, which the *Hebrews* made to go and sacrifice in the Desert, did not surprise *Pbaroab*: It was an universal Practice. As to the high Places, and the *Neomenia*, see *1 Reg.* c. ix. and c. xx. *Ec. pafim in tota Script.* *Horatii Srm.* L 1. Satir. 9. *tricifima Sibta a*, the Feast of the thirtieth Day. It is the *Neomenia*, which comes again after twenty-nine Days. *Jerem.* xliv. 17. and *Buxtorf. Synag.* *Judaic.* c. 17.

† *Maimonid. Ductor Dubitanum*, lib. iii. c. 46.

‡ *Histor. Arabie.* c. xi. and *Hof-inger. Hist. Orient.* lib. i, c. 8.

|| *Huchuyt's Voyages*, Vol. ii. pag. 398.

§ *Anton. Geuffraeus de Turcar. Relig.* lib. ii. p. 53.

¶ *Hercdot. in the Life of Homer, Meursius Græc. scriata. Voca* *raparia S-muel. Petri. in Leg. Attic.* p. 35.

** *Macrob. Saturn.* lib. i. cap. 15. *Plutarch. lib. de Jit. Æm.* *& Horatii Carm.* l. iii. od. 23.

||* Religion of the *Gauls*. In the antient Figures of the Ceremony of the Mistletoe, the Druid wears a Half-moon; because it was at the *Neomenia* the Ceremony was performed.

*† *Alexand. Geraldin. Itinerar.* lib. ix. *Huet. Deuterist. Evangel.* p. 84.

high Places, and their *Neomenia*, have inquired into the Cause of this Conformity, and been divided into two Opinions equally deviating from Truth, but one of which, though false, yet is of no dangerous Consequence, whereas the other is extremely so. The first consists in thinking, that the Heathens took, both from Scripture and the *Hebrews*, the greatest Part of their Practices, even to their Fables, which are, say they, no more than some Particulars of the sacred History altered and disguised. The other Opinion consists in thinking, that the *Hebrews* received from the *Egyptians* and the *Canaanites* the whole Ground of their Law and Ceremonies, which tends to ruin Revelation. The first Opinion, though innocent, and very common, yet is unwarrantable; since the Heathens became acquainted with the Books of the *Hebrews* but very late, and that People, totally separated from and unknown to other Nations, was on no Account fit to serve them as a Pattern. The other Opinion is no less absurd: Since the Law insists, in the most particular Manner, on forbidding the *Hebrews* the Practices of the *Egyptians*, the *Arabians*, and the *Canaanites*. If the *Hebrews* and the Heathens agree together in the Practices of their Sacrifices, Purifications, and Libations, and in their Inclination to gather together upon high Places, and in the Regularity of their *Neomenia*, we must confess that the *Hebrews* are not indebted to the Heathens for these Customs, and that on the other Hand the Heathens did not borrow them from the *Hebrews*; but that both the *Hebrews* and the Heathens had them from the remotest Antiquity, and from the common Source whence they all sprung. I mean from the Family of *Noab*, when the whole was contained in the Plains of *Chaldea*. This Point of Re-union, equally plain and certain, is the only Way to unravel these Difficulties which divided the Learned. The whole of Mankind, being gathered round *Babel*, had already the Practice of the Sacrifices made before, and renewed by *Noah* immediately after the Flood. For want of Writing, what Means could be more natural and more public, to call together to the Sacrifice a Multitude of Families dispersed, than the Sight of the Decline of the Moon, and the Return of

the New? It is even very likely, that the Sun, which before the Flood marked the Course and the Bounds of the Year, by the Diversity of the Stars under which it passed, did it, however, without leaving the *Æquator*, and put no Difference between one Day and another Day, or one Season and another. The Moon was then the most proper Means to mark out the Beginning and the Progress of Months: And *Noab*, when he fixed the religious Meetings at the Time of the *Neomenia*, did but renew what was practised before the Flood. So the Fathers of all Nations, having been long enough under the same Leader, in the same Place, united by the same Wants, the same Language, and the same Practices; it is the plainest Thing in the World to think, that the Custom of meeting in high Places, and at the Return of the new Moon, the Offering of the Fruits of the Earth, the Sacrifices, the common Repasts and the Songs, are all Customs which have with them passed through all the Earth. This is what they have constantly preserved ever since their Dispersion; and in every other Thing, they constantly proceed with making themselves distinguished from each other. You are sensible, how this Agreement of all Nations in the religious Customs, which suited the first Ages, and their infinite Variations in all the rest, concur to testify the Truth of *Moses*'s Narration, and the perfect Knowledge he had of the Origin of Things.

Astronomy, in its Birth, had the Glory of regulating the first Form of public Worship. It was ever since strictly united with Religion, to which it, from Age to Age, rendered new Services in the Course of its Progress; and Astronomy degenerated into Impertinence, or into Superstition, only when Religion was perverted.

After the Introduction, or, if you please, the Restitution of the *Neomenie*, of the Zodiac. by the Observation of the first Phasis of the Moon, they applied themselves to the fixing of the Beginning and End of the Year, by which they had, Time out of Mind, taken care to measure the Life of Man, and to mark the Distances of notable Events. If the Meteors and the Variety of the Seasons were not, any more than the Rainbow, known till

till after the Havock made by the Flood, the Succession of Years became but the more sensible since that great Change. It was an easy Matter for Men to reckon how many Harvests they had got in; and in the poetical Style, such a Number of Springs or Summers are commonly understood by so many Years. But something more than this was wanting, and Necessity brought Astronomy one Step forwarder.

Twelve Lunations one upon another, that is, twelve Revolutions of the Moon successively, departing from and drawing again near the Sun, were not sufficient to bring out the whole Course of a Year; and the Duration of thirteen Lunations exceeded the Year: For twelve Times 29 Days are only 348, and thirteen Times 29, are 377 Days; whereas the Year is only 365 Days and a few Hours. The several Revolutions which the Moon makes in the Heavens, and successively passing and repassing from Month to Month under certain Stars, being then not exactly contained a certain Number of Times in that which the Sun makes by passing pretty nearly under the same Stars, it was not possible to determine the Beginning and the End of the Year by an exact Number of Lunar Revolutions. They were then obliged, in order to know the precise Bounds of the annual Course of the Sun, carefully to examine, what Stars were successively obscured or drowned by the passing of that Globe, and what Stars, beginning to clear themselves from its Rays by reason of its Remoteness, shewed themselves again before the Dawn of Day.

They might, i. e. is true, have resumed the Method of Calculation, which was in Use before the Flood *: But it would have been insufficient upon many Accounts. For, though the Sun did perhaps still pass under the same Stars as before; its Fires, whose Influence was even and uniform before the Flood, had ever since been sometimes brisker, sometimes fainter. The Sun itself seemed to change the Points of its Rising and Setting. It ascended its Meridian much higher at one Time than at another. These Novelties required new Observations, and they endeavoured, not indeed to understand the Structure of the World, or the Reason of

all these great Effects, but in the Heavens to shew Men some precise Marks of the Progress of the Year, and some sure Methods of regulating the Times of their Works. They obtained both these useful Points: The first, by making themselves Masters of the certain Knowledge of the Stars under which the Sun passes, and which are in his Way from the Moment he goes from any first Star taken at Discretion, to the Instant of his coming again under the same. Secondly, By giving these Stars such Names as might characterize what was peculiar to every Part of the Year, or what was actually done upon Earth, when the Sun was under such or such Stars. Astronomy, by this twofold Caution, was from its Beginning a popular Science, and it made Heaven a Book always open, to which Mankind might come for Information.

Antient Tradition has handed down The Division of the Zodiac. to us the ingenious Method which the first Men made use of to know exactly the Line which the Sun describes under the Heavens in the perpetual Changings of its Place, and to divide the Year into equal Portions. This Tradition is found again in two antient Authors, the one *Roman* *, the other *Greek* †. The first attributes it to the *Egyptians*; the other, and more justly, to the first Inhabitants of *Chalœa*, who are the Fathers of Astronomy, as well as of all Mankind.

They every Day saw the Sun and the whole Heaven turning and passing from East to West. In the mean Time they observed, that the Sun, by a Motion peculiar to it, from Day to Day receded from some certain Stars, and took its Place under others, always advancing towards the East. Whilst the Moon was making twelve Times that Revolution, the Sun made it only once: But she began the thirteenth again, before the Sun had as yet compleated its Course. The Habit of dividing the Year into pretty near twelve Lunations, made them wish, that they had twelve Divisions

* *Macrobi. in somn. Scip. I. i. c. 21.*

† *Sext. Empiric. lib. v. adversus Mathematicos.*

sions of a Year perfectly equal, or twelve Months which might be exactly equivalent to the Year itself, and which might, as it were, be pointed at with one's Finger in the Heavens, by shewing some certain Stars under which the Sun passes during every one of these Months. Here is then the Method in which they divided the Course of the Sun in twelve equal Portions or Collections of Stars, which are called *Asterisms* or Constellations. Our Chaldeans took a Couple of Brass open Vessels, the one pierced at the Bottom, and the other without any Orifice below. Having stopped the Hole of the first, they filled it with Water, and placed it so as that the Water might run out into the other Vessel, the Moment the Cock should be opened. This done, they observed in that Part of the Heaven, where the Sun has its annual Course, the Rising of a Star, remarkable either for its Magnitude or Brightness; and at the critical Instant it appeared on the Horizon, they began to let the Water flow out of the upper Vessel into the other during the rest of the Night, and the whole following Day, to the very Moment when the same Star, being come to the East again, began to appear anew on the Horizon. The Instant it was again seen, they took away the Under-vessel, and threw the Water that remained in the other on the Ground. The Observers were thus sure of having one Revolution of the whole Heaven, between the first Rising of the Star and its Return. The Water, which had flowed during that Time, might then afford them a Means of measuring the Duration of one whole Revolution of the Heaven, and of dividing that Duration into several equal Portions; since by dividing that Water itself into twelve equal Parts, they were sure of having the Revolution of a twelfth Part of the Heaven during the Efflux of a twelfth Part of the Water: They then divided the Water of the Under-vessel into twelve Parts perfectly equal, and prepared two other small Vessels capable of containing exactly one of those Portions and no more. They again poured into the great Upper-vessel, the twelve Parts of Water all at once, keeping the Vessels shut. Then they placed under the Cock, still shut, one

of the two small Vessels, and another near it to succeed the first, as soon as it should be full.

All these Preparations being ready, they the next Night observed that Part of the Heaven towards which they had for a long while remarked that the Sun, the Moon, and the Planets, took their Courses, and staid for the Rising of the Constellation, which is since called *Aries*. The Greeks, perhaps, gave that Name to some Stars different from those which went by it before the Flood: But this Enquiry is not necessary at present. The Instant *Aries* appeared, and they saw the first Star of it ascending, they let the Water run into the little Measure. As soon as it was full, they removed it, and threw the Water out. In the mean Time they put the other empty Measure under the Fall. They observed exactly, and so as to remember very well, all the Stars that rose during all the Periods which the Measure took in filling; and that Part of the Heaven was terminated in their Observation by the Star which appeared the last on the Horizon, the Moment the Measure was just full; so that by giving the two little Vessels the Time necessary to be alternately filled to the Brim three Times each during the Night, they had by that Means one Half of the Course of the Sun in the Heaven, that is, one Half of the Heaven itself; and that Half was again divided into six equal Portions, of which they might shew and distinguish the Beginning, the Middle, and the End, by Stars, which from their Size, Number, or Order, were rendered distinguishable. As to the other Half of the Heaven, and the six other Constellations which the Sun runs over therein, they were forced to defer the Observation of them to another Season. They stood till the Sun, being placed in the Middle of the now known and observed Constellations, should leave them at Liberty to see the others during the Night.

Doubtless some Precautions are necessary, not to mistake as to the Fall of the Water, which must flow more slowly in Proportion as its Mass is less high. However, after having by this, or some such Means, made themselves sure of the great annual Course, which the Sun faithfully follows in the Heavens, and of the Equality of

of the Spaces filled by the twelve Collections of Stars that limit that Course, the Observers thought of giving them Names. They in general called them the Stations, or the Houses of the Sun, and assigned three of them to each Season. They then gave each Constellation a peculiar Name, whose Property did not only consist in making it known again to all Nations, but in declaring at the same Time the Circumstance of the Year (which was of Concern to Mankind) when the Sun should arrive at that Constellation.

Formerly, Sir, I observed to you (but this is the proper Place to remember you of it) that the Names, by which the twelve Asterisms of the great and annual Circle actually go, had been taken from the most important Events, that happen either in the Heavens or on the Earth, as the Sun successively takes Place under every one of them.

By a particular Care of Providence, the Dams of the Flocks commonly happen to be pregnant about the End of Autumn. They bring forth during the Winter, and in the Beginning of the Spring. Whence it happens that the young ones are kept warm under the Mother during the Cold, and afterwards easily thrive and grow active at the Return of Heat. The Lambs come the first; the Calves follow them, and the Kids fall the last. By this Means the Lambs, grown vigorous and strong, may follow the Ram to the Fields as the fine Days come on. Soon after the Calves, and at last the Kids venture abroad, and by increasing the Flock begin to augment the Revenues of their Master.

Our Chaldean Observers, seeing that there were, during the Spring, no Productions more useful than Lambs, Calves, and Kids, gave the Constellations, under which the Sun passes during that Season, the Names of the three Animals which inrich Mankind most. The first was named *Aries*, the second *Taurus*, the third *the two Kids (Gemini)* the better to characterize the Fecundity of Goats, which more commonly bring forth two young ones than one, and an Abundance of Milk more than sufficient to nourish them.

The Constella-
tions of the
Spring.

The

The Constella-
tions of the
Summer.

The Bulk of Mankind, united in the Plains of Irak, had already very often remarked, that there was a Point to which the Sun raised itself in its coming towards them, but which it never exceeded; and that it afterwards sunk daily, in receding from them for six Months together; till it arrived at another Point a great Way under the first, but below which it never descended. This Retreat of the Sun, made very slowly, and always backward, gave the Observers the Occasion of distinguishing the Stars, which follow the two *Kids*, or *Gemini*, by the Name of the Animal that walks backward; *viz.* the *Crab*. When the Sun passes under the next Constellation, it makes our Climate feel sultry Heats, but chiefly the Climates where Men were at that Time all gathered together. When Poets attribute to that Constellation the Fierceness * and Raging of the *Lion*, of which it bears the Name, it is very easy to guess at what might determine that Choice from the Beginning. Soon after, the housing of the Hay and the Corn is entirely over throughout the East. There remain on the Ground only a few Ears scattered here and there, which they caused to be gleaned by the least necessary Hand. This Work is left to the youngest Girls. How then could they represent the Constellation under which the Sun sees no longer any Crops on the Ground, better than by the Name and Figure of a young Maid glean- ing? The Wings you see her have in the Spheres are Ornaments added of later Date, after the Introduction of Fables. The *Virgin*, which follows the *Lion*, is certainly no other than a gleaning Girl, or, if you will, a Reaper; and lest we should mistake her Functions, she besides has in her Hand a Cluster of Ears: A very natural Proof of the Origin I here attribute to her.

The Constella-
tions of Au-
tumn.

The perfect Equality of Days and Nights, which happens when the Sun quits the Sign of *Virgo*, caused Astrono- mers to give the next Sign the Name of *Libra*, that is, of a Balance. The frequent Diseases which

* *Furit & stella vesani leonis.* Horat. Carm. l. iii. od. 29.

which the Sun leaves behind him, or causes by his retiring, procured the next Sign the Name of *Scorpio*, because it is mischievous, and drags after it a Sting and Venom. Towards the End of Autumn, the Fall of the Leaf exposes wild Beasts, leaving them less Covering: Vintage and Harvest are over: The Fields are free, and it is of ill Consequence to suffer the Propagation of Beasts at the Approach of Winter. Every Thing then invites us to hunt, and the Sign, in which the Sun is at that Time, has from thence obtained the Name of *Sagittarius*; that is, the Archer or Huntsman.

What is the proper and distinctive Character of the wild Goat, or *Capricorn*, of which the first Sign in Winter has the Name? It is to look for its Food, getting from the Foot of the Mountains to the highest Summit, and always climbing from Rock to Rock*. The Constellations of the Winter.

*Dès que les Chevres ont brouté,
Certain esprit de liberté
Leur fait chercher fortune: Elles vont en voyage
Vers les endroits du pâturage
Les moins fréquentés des humains.
Là, s'il est quelque lieu sans route & sans chemins,
Un rocher, quelque mont pendant en précipice,
Elles y vont promener leurs caprices
Rien ne peut arrêter cet animal grimpant.*

La Fontaine.

The Name of *Capricorn* was then fit to inform Men of the Time when the Sun, having reached the lowest Verge of its Course, was ready to begin to ascend again towards the highest, and to continue to do so for six Months together. This is quite the Reverse of the Crab (*Cancer*); and the happy Concurrence of the opposite Characters of these two Animals, is a Proof of what directed

* *Capricornus ex infernis partibus ad supra solem reducens, capras naturam videtur imitari, quæ dum pascitur ab imis partibus semper prominentium scopulorum alta deposita.* Macrob. Saturnal. 1. i. c. 21.

directed the first Observers in the Imposition of all these Names *.

Aquarius and *Pisces* without any Difficulty mark out the rainy Season, and the Time of the Year when Fishes, fatter and nicer than in any other Time, bring on again the Profit and Pleasures of Fishing.

It may be remarked, that of the twelve Constellations, there are ten, the Names of which are borrowed from several Animals; which caused Astronomers to give the annual Circle, which they compose, the Name of *Zodiac*. It is as much as if you should say, the Circle of Animals.

By this very plain Industry, Men acquired a new Method of measuring Time, and of regulating all their Works. They already knew, without any Trouble or Care, how to regulate the Order of their Feasts and common Business, by Inspection only of the Phases of the Moon. From the Knowledge of the *Zodiac*, they obtained an exact Knowledge of the Year: The Constellations became to them so many very significant Signs, which, both by their Names and respective Situations, informed them of the Order of their Harvests, and of the Cautions they were to take, in order to bring them about, openly and daily shewing them, how long they were to stay for them; the People were neither obliged to cast up the Days, or mark out the Order of Times to regulate themselves. Twelve Words applied to twelve different Parts of the Heaven, which every Night revolved before their Eyes, were to them a Part of Knowledge no less convenient and advantageous, than easy to be acquired. When Men, after the Setting of the Sun, saw the Stars of the Sign *Aries* ascend the opposite Horizon, and distant from the Sun by one Half of the Heaven, they then knew that the Sun was under the Sign *Libra*, which being the seventh of the celestial Signs, was distant from the first by one whole Half of the *Zodiac*. When at the Approach of Day they saw in the Middle of the Heaven,

and

* Ideo autem bis duobus signis, quæ portæ solis vocantur, *Cancro* & *Capricorno*, hæc nomina contigerunt, quod Cancer animal retro arque oblique agit: eademque ratione sol in eo signo obliquum (ut solet) incipit agere retrogessum. Capræ vero consuetudo hæc in pastu videtur, ut semper altum pascendo petat: sed & sol in Capricorno incipit ab imis in alta remaneat. *Saturnal.* l. i. c. 17.

and at an equal Distance from East and West, the finest Star of the Sign *Leo*, they easily understood, that the Sun, then ready to rise, was at the Distance of three Signs from *Leo*, and removed towards the East one quarter Part of its Circle. Thus, without seeing the Stars which the Sun drowned by its Brightness as he came under them, they said with a perfect Assurance, the Sun is now in *Scorpio*; two Months hence we shall have the shortest Day. They could, on Sight of a single Constellation, placed in the Eastern, or Middle or Western Part of the Heaven, immediately say where the Sun was, how far the Year was advanced, and what Kind of Work it was fit they should busy themselves about. After this Manner Shepherds and Farmers still regulate their Works; and if we at present are now ignorant of the Names of the Stars, if we are not able to determine the Distance between one Constellation shewn us, and the actual Place of the Sun, it is because we can read and write. The first Men perused the Heavens for want of Writing; and it is on Account of the Conveniency of Writing, that the Generality of Men now dispense with looking among the Stars, for the Knowledge of the Operations and Order of the Year. But Writing itself, that so useful Invention, is one of the Products of Astronomy; and it may be easily shewn you also, that the Names given the twelve celestial Signs, gave Birth to the Invention both of Painting and Writing. This History promises you a very agreeable Novelty, and it will continue to inform you of the Helps, for which we are indebted to the Study of Nature.

It seems that Painting was known before Writing. Astronomy gave Birth to Painting: They both afterwards concurred to cause the Art of Writing to be invented. Eight of the Figures of the Zodiac have so evident an Analogy with the Animals or Objects of which they have the Names, that we cannot doubt, but that they are Pictures of them. The first A is a Sketch of the Horns of the Ram (*Aries*). The second B visibly is the Fore-part of a Bull's Head. The third C is the Union of the two Heads of Kids. The seventh G is nothing but the Beam of a Balance. The eighth H is a slight Sketch of the Paws, the long Tail and the Sting of a Scorpion. The ninth I is the Arrow itself

The Invention
of Writing.

of

of the Archer or Hunter, whose Name it goes by. The eleventh L is the Expression of a Current of Water; and the twelfth M that of two Fishes set Back to Back. These other four D, E, F, K, resembling their respective Objects at first, have been altered in Time, for the Convenience of Abbreviation.

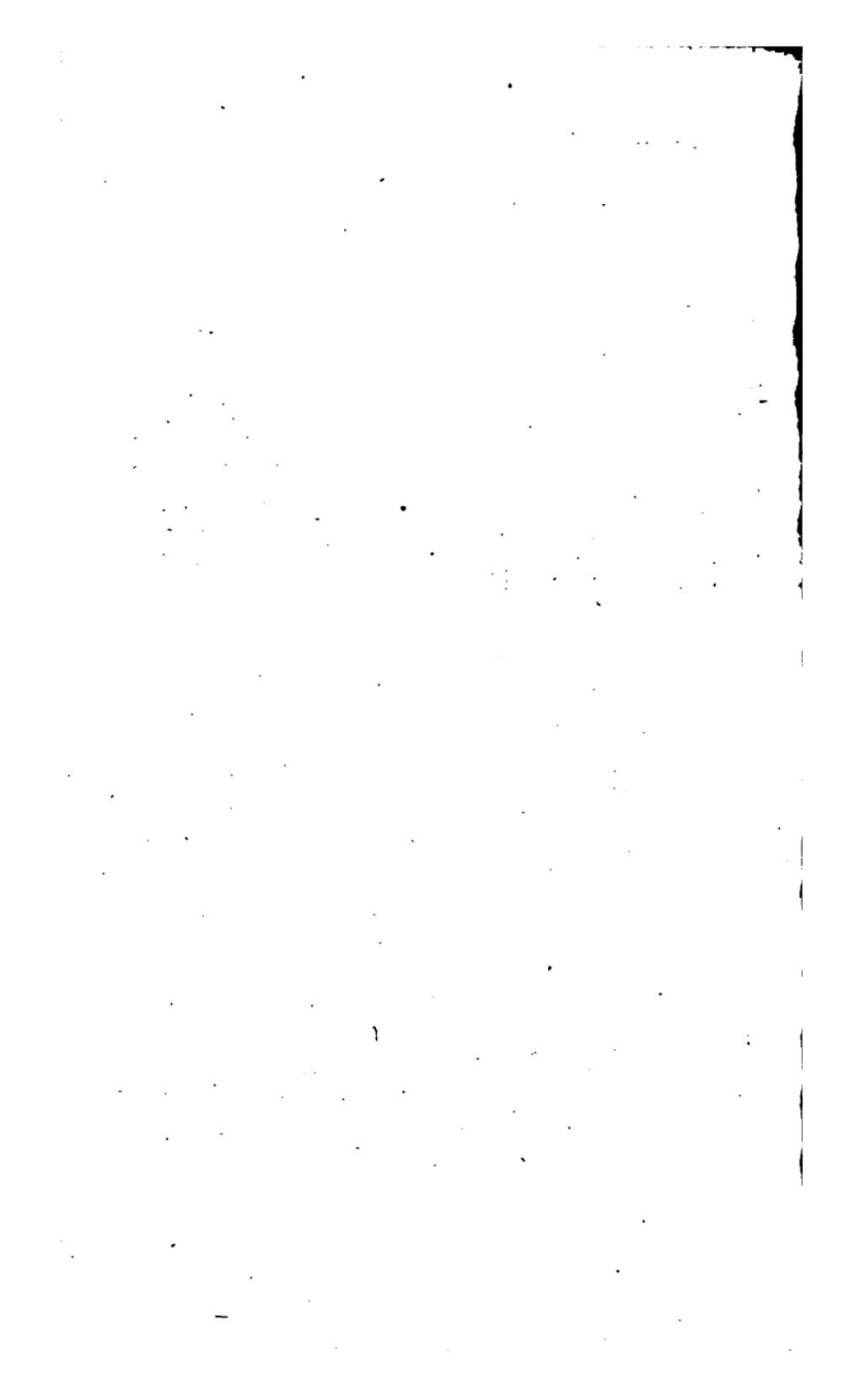
I dare not presume to affirm, that these current Abbreviations are of the greatest Antiquity: But the iatire Figures of the celestial Signs being frequently found in the Monuments of the *Egyptians*, which are known to be of a Date but little distant from that of the Flood, we may thence judge of the Antiquity of the Zodiac, and of the Representation which was made of it for regulating the People. This Painting was the Foundation of the Art of Writing; since by shewing something to the Eye, it gave the Mind something more to understand. This convenient Invention got Ground by Degrees. The *Egyptian* that imagined some other Symbols, relative to the Wants and peculiar Productions of *Egypt*. For Instance, the Symbol of the Sun, which regulates the Course of Nature, was a Man armed with a Whip like a Coachman, or adorned with a Scepter like a King, and that Figure was called *Osiris* *, that is, the Leader, the Inspector, or the King. The Earth, which produces every Thing, and incessantly varies its Productions, was represented under the Symbol of a teeming Woman, whose Attributes were varied according to the Feasts or Works they had a Mind to proclaim; and the Name of this Figure was *Iris*, that is, the Woman, or Queen. The Crescent, which was the Mark of the *Neomenia*, or the Assembly of the People, being put on her Head with such or such another Attribute, might mark out the Assembly of this or that Season. The bright Star of the Dog, which begins to appear in the Morning before Dawn, and to disengage itself from the Rays of the Sun, when it enters the Sign *Leo*, was the infallible Mark of the Time when the *Nile* was to overflow. It warned the *Egyptians* to retire immediately to the higher Grounds, to lay in their Stores of Victuals, and to avoid all Surprize. It performed for them the Office of that Animal, who warns his Master of the Approach

of

* *Plutarc. de Isid. & Osir.*



1. Osiris with a Key, a Whip, and a Crab upon his Foot; the public Sign of the beginning of the Solar year under Cancer. 2. Ius, or the Public Sign of the Acoomoria. 3. Anubis, or the public Sign of the rising of the Dog-star, occurring with the beginning of the year. 4. The Sphinx, or the Mark of the duration of the inundation.



of Thieves. Wherefore it was represented under the Figure of a Dog, or of an human Body, having a Dog's Head, with Wings on its Feet, and a Kettle on the Arm. This was a Language easy to be understood by all. In order to point out to them the Repose and State of Inaction they would be in, during their Retreat, and the Inundation, which was to last almost all the Time that the Sun should be under the Signs *Leo* and *Virgo*; they placed on the Edges of Terraces the Figure of the Sphinx, made up of a female Face, and the Body of a Lion couching and inactive. The first and great Concern of the *Egyptians* was, to know the Return and Duration of the *Etesian* Wind, which collected the Vapours in *Aethiopia*, and caused the Inundation, by blowing from North to South towards the End of the Spring *. Their next was to know the Return of the South Wind, which helped on the flowing of the Waters towards the *Mediterranean*. But how should they represent the Wind? In order to this, they chose the Figure of a Bird †. The Hawk, which spreads his Wings, looking to the South, to renew his Feathers at the Return of the Heats, was made the Symbol of the *Etesian* Wind, which blows from North to South: And the Whoop, which comes from *Aethiopia*, to find Worms in the Slime after the Draining of the Waters of the *Nile*, was made the Symbol of the South Winds necessary to the Efflux of the Waters. These few Examples may give you a Notion of the symbolical Writing of the *Egyptians*. It is peculiar to them, from the extensive Use they made of it. But the Invention of the Zodiac, which occasioned it, is more antient than the *Egyptian* Colony, and comes from the Plains of *Shinar*: For, had the *Egyptians* been the first Authors of the Names of the celestial Signs, they would not have placed the Figure of a young gleaning Maid after the Sign *Leo*, for a Mark of the Harvest, which is indeed finished at that Time in other Places, but is still at a very great Distance in *Egypt*. All then being under Water, they are obliged to defer Sowing till towards the latter End of November, that they may in *March* or *April* get in their Corn, which is thus but four Months a ripening.

This

* *Plutarc. de Isid. & Osir.*

† *Job xxxix. 29.*

for real ones, which had the Power of foretelling future Events, the Birds themselves were most earnestly and religiously consulted. Judge what Answers could be had from them. The whole antient Ritual, which was symbolical, having been literally taken, the World was filled with Errors, Idolatry, and Superstitions. I shall here enter upon a Subject infinitely engaging, and offer to you the Means of accounting, in the plainest Manner, why Idolatry, Superstitions, and Fables, have always united three particular Characters; the one, of having Relation to the Heaven and the Stars; the other, of having Connections with Names and Facts, drawn partly from sacred, partly from profane History; and the third, of every where offering us a few Remains of Truths, blended with a horrid Mixture of Notions infinitely absurd. But we could never engage in the Origin of Idolatry, and of the Extravagance of Divinations, or of Astrology, without deviating from the View of Nature, and from the History of the Study made of it. Let us go on with considering its Progress. I shall perhaps try, in a select Treatise, to satisfy you concerning the Origin of the poetical Heaven, on the Falsity of the Chaos, which has seduced Philosophers as well as Poets; and finally, on the perfect Agreement of Experience with the Physics of Moses*.

* You will find this Subject treated at large in a Book intitled, *The History of the Heavens*.

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THE
DISCOVERY
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POLAR STAR.

The Voyages of the ANTIENTS.

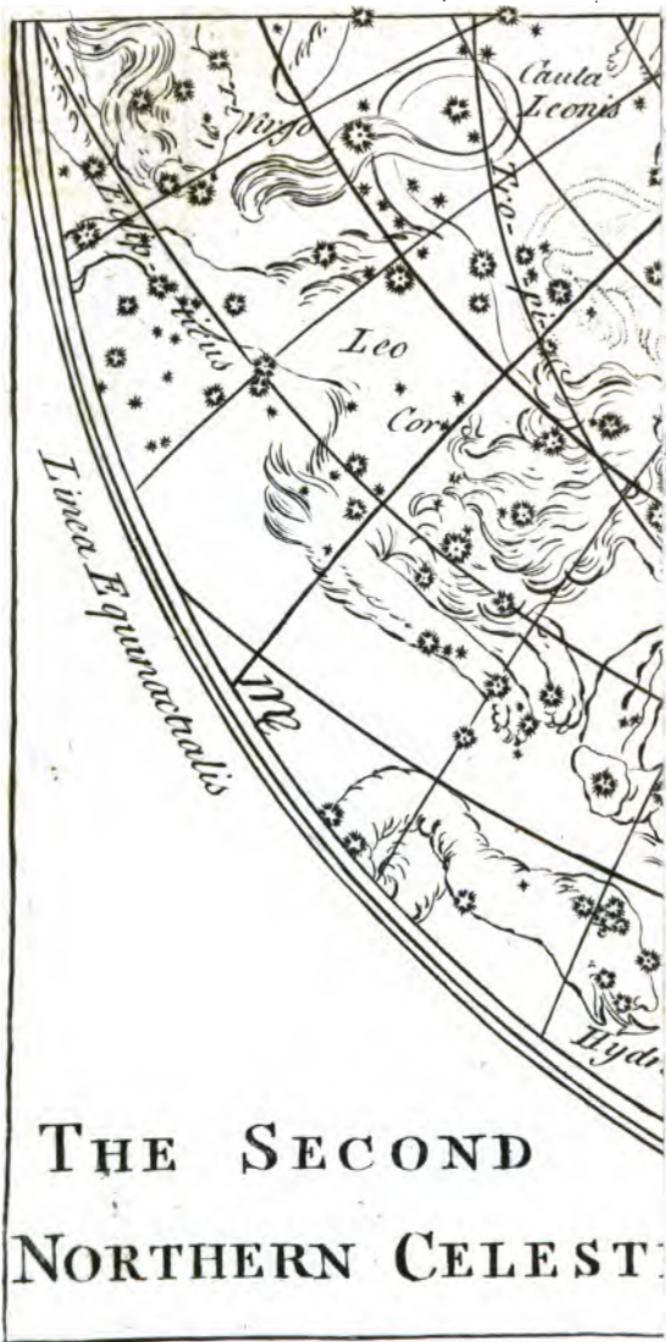
DIALOGUE II.

IN the History I gave you of the first Informations Mankind received concerning Astronomy, Physics, and Husbandry, I at the same Time, my dear Chevalier, hinted at the Source and Beginning of those enormous Mistakes, which the forgetting of these Informations had occasioned. Without tracing Idolatry through all its Branches, I think I have shewn you, by a sufficient Number of Circumstances, the Concurrence of which can not be an Effect of Chance, that the Figures of Men, Women, and Animals, which are delineated in antient Writing, and which related to the various Feasts and Operations of the Year, have through Ignorance been changed into so many celestial, terrestrial, and infernal Powers. The little I told you of this is sufficient to make you observe, in the Variety of the symbolical Figures, and of the representative Ceremonies annexed to them, the Origin and Explanation of the monstrous Deities

Deities whom our Forefathers adored, and of the no less monstrous Opinions, which from Age to Age, even to our own, have enslaved the Minds of Men, weakened true Piety, and led the Learned astray in their Study of Nature. But though the greatest Philosophers dis-honoured themselves, either by their Affection for Idolatry, or by their Prejudice in Favour of judicial Astrology, or even by their Irreligion ; we have sufficiently exposed their Failings. Let us now turn our Eyes from these, to see the Good only that was in them, and the Legacies they have left us. From the History of their Mistakes, on which I shall in another Place, and more at Leisure, be very particular, let us return to that of their Industry.

The Discovery was no longer the same as before the Flood, first diverted the Attention of Men to the new Course of the Sun, and made them invent the Zodiac, Writing, Surveying of Land, Hunting of wild Beasts, and the Method of regulating the public Order of their Feasts and Labours. The Exigencies of Trade, of Transportations, and of Navigation, caused Men afterwards to find out in the Heaven, the Situation and Motions of both the Bears.

They saw most of the Stars ascending the Horizon as well as the Sun, then rising up obliquely, and, like him, approach the Place where it appears at Noon ; then draw towards the West, and hide themselves under the Earth. But Navigators observed, that there were some Stars which never set, and which every Night, in fair Weather, were seen on that Side where the Sun never appears : Or in other Words, on their Left Side, when their Eyes were turned towards the East. They did not long hesitate on the Use they might make of these Stars, which always shewed them the same Side of the World ; and when foul Weather put them out of their Way, and turned the Head of their Vessel towards these Stars, which they had before on their Side, they naturally steered so as to place the Ship in its first Situation, with regard to these constant Stars. The Immobility of that Part of the Heaven became the Rule and Security of Navigators. These Stars, by appearing again, indicated to them their Course, and as it were

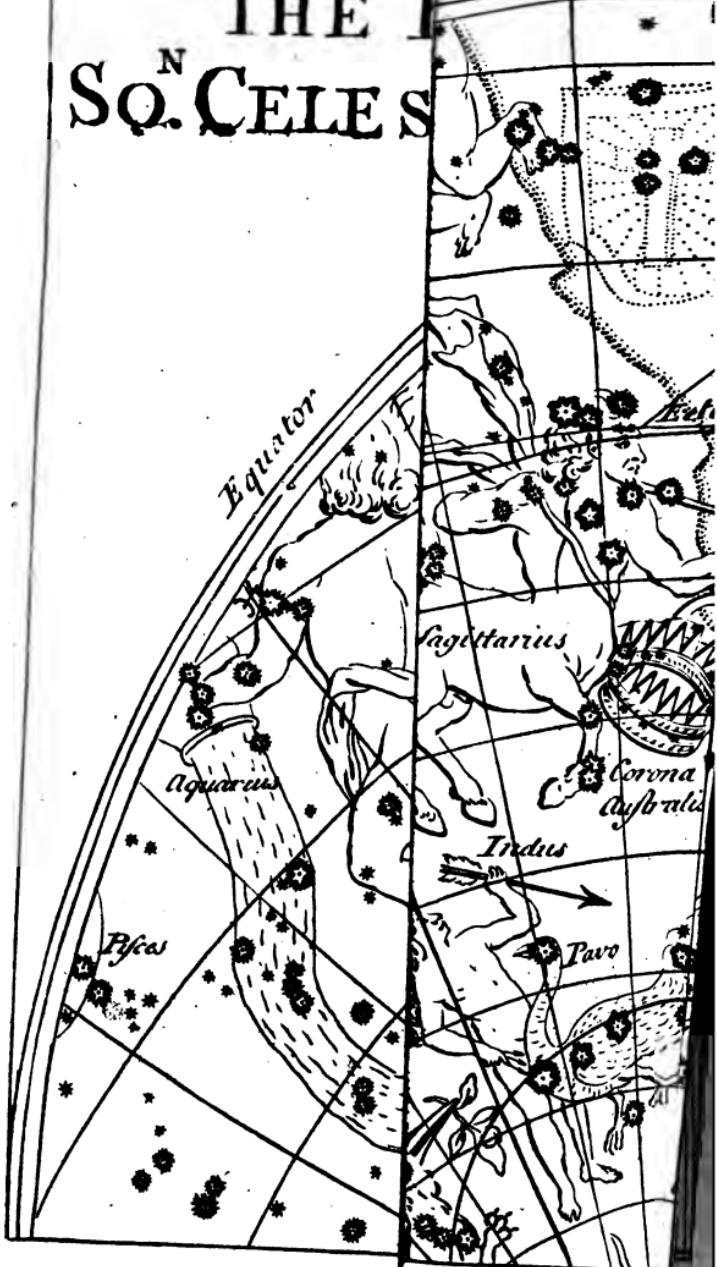


THE SECOND NORTHERN CELESTIAL





THE S^N CELES



them. This important Signification of that Part of the

it was most easy to discern. None appears more remarkable, than that which of several Stars, among which they reckon the brightest Sort, and which takes up a pretty

The People who saw this Constellation above, sometimes below, sometimes on one ways beginning the same Revolution again, called *Terio* the heavy Carts they used to draw of Corn withal †, and to clear them of that they gave the seven finest Stars of that on the Name of *Septentrio*. But the Phoenicians, who had their Eyes incessantly fixed on it by its Instructions, with greater Reason called it *Parraſis* ‡, the *Instruction*, the *Indication*, the sometimes *Calitſa* § or *Calliſo*, that is, the Deliverance, the Safety of Sailors, but much more commonly *Dobebé*, or *Doubé* §, a Name which Astronomers still, and which signifies the *Speaking Constellation*, *Constellation that gives Advice*.

Il Fortune the self-same Word *Doubé* signified also to bear in the Language of the Phoenicians, who communicated it to the Greeks only in that Sense, quite different to the Figure or the Uses of the Constellation. It is however retained to this Day the Name it bore from thence. You have seen the pretty Stories which Ovid and other Poets have published about that She-bear. They make her a Maid called *Calliſo*. They suppose her to be born at *Parraſa*, an Arcadian City, and are fully acquainted with both her Genealogy and Adventures. Jupiter being angry, on seeing that the Jealousy of Juno had changed *Calliſo* into a She-

Vol. IV.

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bear,

* Ἀριόν οὐν καὶ ἐμαζεῖται ἐπικληνούσι καλέσοι. Π. Σ.

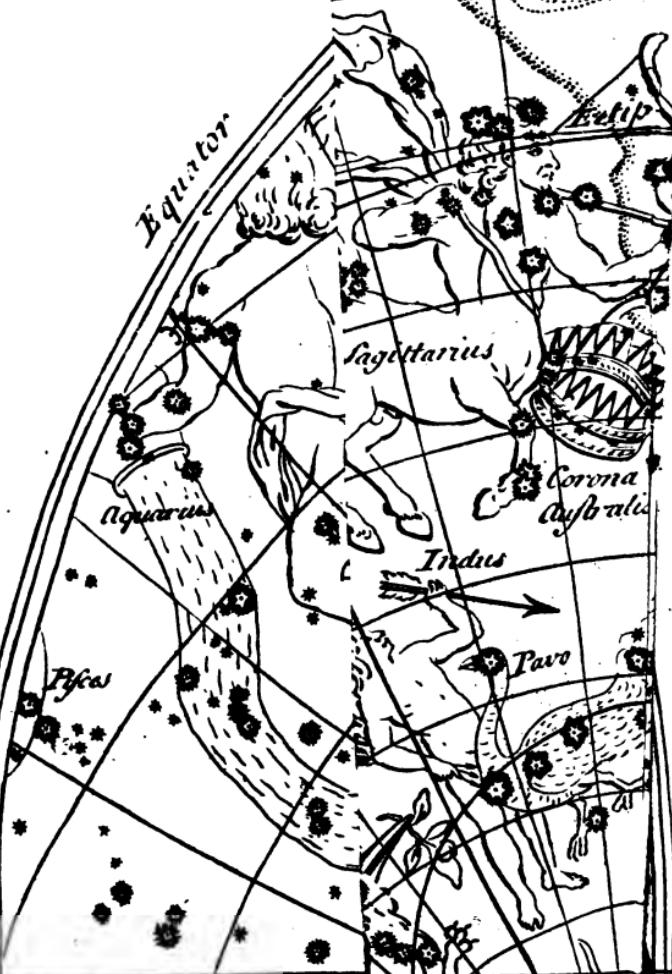
† *Terendis frugibus.*

‡ *Parraſa*, Indication, from *παρεῖ* *Parraſis*, to shew, to clear, to teach. Whence came the Name *Pbariſe*, or *Doctor*, probably,

§ *κατέσθι* *Calitſa*, Deliverance; from *κατά* *Calat*, to save, to deliver.

§ From *דָבָב* *Dabab*, to speak, comes *Dobebé* or *Doubé*, she that speaks,

THE N^o CELES



spoke to them. This important Study taught them a more exact Study of the Constellations of that Part of the Heaven, which it was most easy to discern. None appeared on that Side more remarkable, than that which is composed of several Stars, among which they reckon one of the brightest Sort, and which takes up a pretty large Space. The People who saw this Constellation sometimes above, sometimes below, sometimes on one Side, and always beginning the same Revolution again, called it the *Wheel*, or the *Chariot* *: And it is because the Romans called *Terio* the heavy Carts they used to draw the Ears of Corn withal †, and to clear them of the Corn; that they gave the seven finest Stars of that Constellation the Name of *Septentrio*. But the Phœnician Pilots, who had their Eyes incessantly fixed on it to receive its Instructions, with greater Reason called it sometimes *Parrasis* ‡, the *Instruction*, the *Indication*, the *Rule*; sometimes *Calisfa* § or *Callisto*, that is, the *Deliverance*, the *Safety* of Sailors, but much more commonly *Dobebé*, or *Doubé* §, a Name which Astronomers give it still, and which signifies the *Speaking Constellation*, the *Constellation that gives Advice*.

By ill Fortune the self-same Word *Doubé* signified also a She-bear in the Language of the Phœnicians, who communicated it to the Greeks only in that Sense, quite foreign to the Figure or the Uses of the Constellation. It has however retained to this Day the Name it borrowed from thence. You have seen the pretty Stories which Ovid and other Poets have published about that same She-bear. They make her a Maid called *Callisto*. They suppose her to be born at *Parrasa*, an Arcadian City, and are fully acquainted with both her Genealogy and Adventures. Jupiter being angry, on seeing that the Jealousy of Juno had changed *Callisto* into a She-bear,

* Ἀφίσον θήνει καὶ ἀπαγγείλειν λαλεῖσι. II. 2.

† *Terendis frugibus.*

‡ פָּרָסָה *Parrasa*, Indication, from פָּרָשׁ *Parash*, to shew, to clear, to teach. Whence came the Name *Pbarisee*, or *Doctor*, probably,

§ כָּלִיסָה *Calisfa*, Deliverance; from קָלָסָה *Calas*, to save, to deliver.

§ From דָּבָב *Dabab*, to speak, comes *Dobebé* or *Doubé*, she that speaks.

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that it always is seen towards the same Point of the Heaven. We for this Reason call it the *Polar Star*, and those, who sail on the *Mediterranean*, call it *Transmontane* *, because they see it over those Countries which are *trà monti*, that is, on the other Side the *Alps*.

The Knowledge of the Polar Star rendered Navigation more bold and prosperous. Before *Thales the Milesian*, who had learned from the *Phœnicians* the important Use of this Observation, had communicated it to the *Greeks of Ionia*, and through these to all *Greece*, near six hundred Years before Christ, these People carried on their Commerce with the utmost Circumspection and Timidity. They sailed along the Coasts, and not only durst not venture far from them, but they never undertook any long Voyage. The Reader is amazed at the Alarms, Deliberations, and great Preparations of *Homer's Heroes*, when they are to cross the *Egean Sea* †. You may have observed that *Virgil*, always mindful of introducing a perfect Conformity between the Adventures of his Hero and the Customs of the Time in which he places him, makes him coast along the Shore of *Greece*, *Italy*, and *Sicily*, without leading him through the main Sea, as it was natural he should. After he had brought him to the Extremity of *Italy*, he causes him to make the long Circuit of *Sicily*, rather than convey him to the Mouth of the *Tiber*, through the Streights of *Messina*; in which they at that Time were afraid of meeting with *Charibdis* and *Scylla*, which frightened no body in the Time of *Virgil*. But nothing made a greater Noise before the Siege of *Troy*, than the Expedition of the *Argonauts*, that is, the Passage of the *Proponitis* ‡, and of the *Pontus Euxinus* ||. It was looked upon as a wonderful Exploit: It became the Subject of the finest Poems: Nay, the Gods themselves were amazed at the

K 2

Bold.

* Therefore the *French* say of a Man, " he has lost the *Transmontane*," when his Affairs are disordered, and he has no Resource left, or any Means to unravel them. He is like a Pilot, who has lost Sight of the Star.

† See the *Odyss.* Book iii.

‡ Now the Sea of *Marmora*, between the Streights of the *Dardanelles*, and that of *Constantinople*.

|| Now the *Black Sea*.

Boldness of the Undertaking ; and in order to ~~eternal~~ this Event, they placed in the Heaven, among the brightest Constellations, the admirable Ship which had been able to pass from *Colchis* * to the Mouth of the *Pbæse*. This now is done by the meanest Turkish Barks.

While the Want of the Knowledge of the Stars, especially of the Polar Star, rendered the Greeks so timorous at Sea, Navigation, on the contrary, was extremely improved by that Assistance among the Phœnicians, and had made their Territory (which was but a Border of *Syria*, of little Extent in Length, and of almost no Breadth at all) a most wealthy and renowned State. They had at that Time Correspondences, and even very good Establishments, in all the Coasts of the *Mediterranean*. We find again their Colonies † and a Multitude of proper Names of their Tongue, in the inner Parts, and on the three Coasts of *Sicily*. It is the same with the six other chief Islands of the *Mediterranean*, viz. *Sardinia*, *Coryra* ‡, *Crete* §, *Cyprus*, *Eubœa* §, and *Lebos* ‡. We find again the same Proofs of their sojourning, or of their frequent Passages to and from the Islands of the second Order, such as are *Lemnos*, *Chios*, *Saros*, *Naxos*, *Rhodes*, *Zante*, *Cephalonia*, and the three *Baleares* **. They discovered all the smallest Islands, and made them known. These are the *Cyclades* on the left Side of the *Archipelago*, and the *Sporades* scattered on the Right. The Cities of *Adruncet*, *Clypea*, *Carthage*, *Utica*, *Hippone*, and a great many others along the Coasts of *Barbary*, are so many Establishments, which the *Sidonians* and *Tyrians* made there at several Times. They had many Sea-ports in *Spain*, especially in the *Bætica*, which is the modern *Andalusia*. All that Country, and particularly the *Rætis* or *Guadalquivir*, which waters it, went

at

* A City of *Tleffyl* at the Bottom of the Gulph, where the City called *Demetriade* was built long after.

† See the *Canons* of *Samuel Bochart*.

‡ Now *Corfou*, at the Entrance of the Gulph of *Venice*.

§ Now *Candia*, below the *Archipelago*.

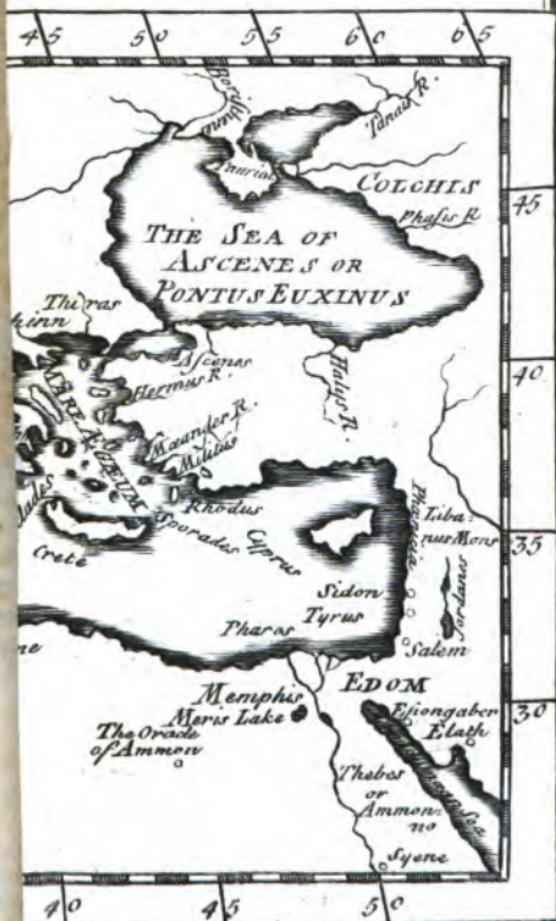
|| Now *Negropont*.

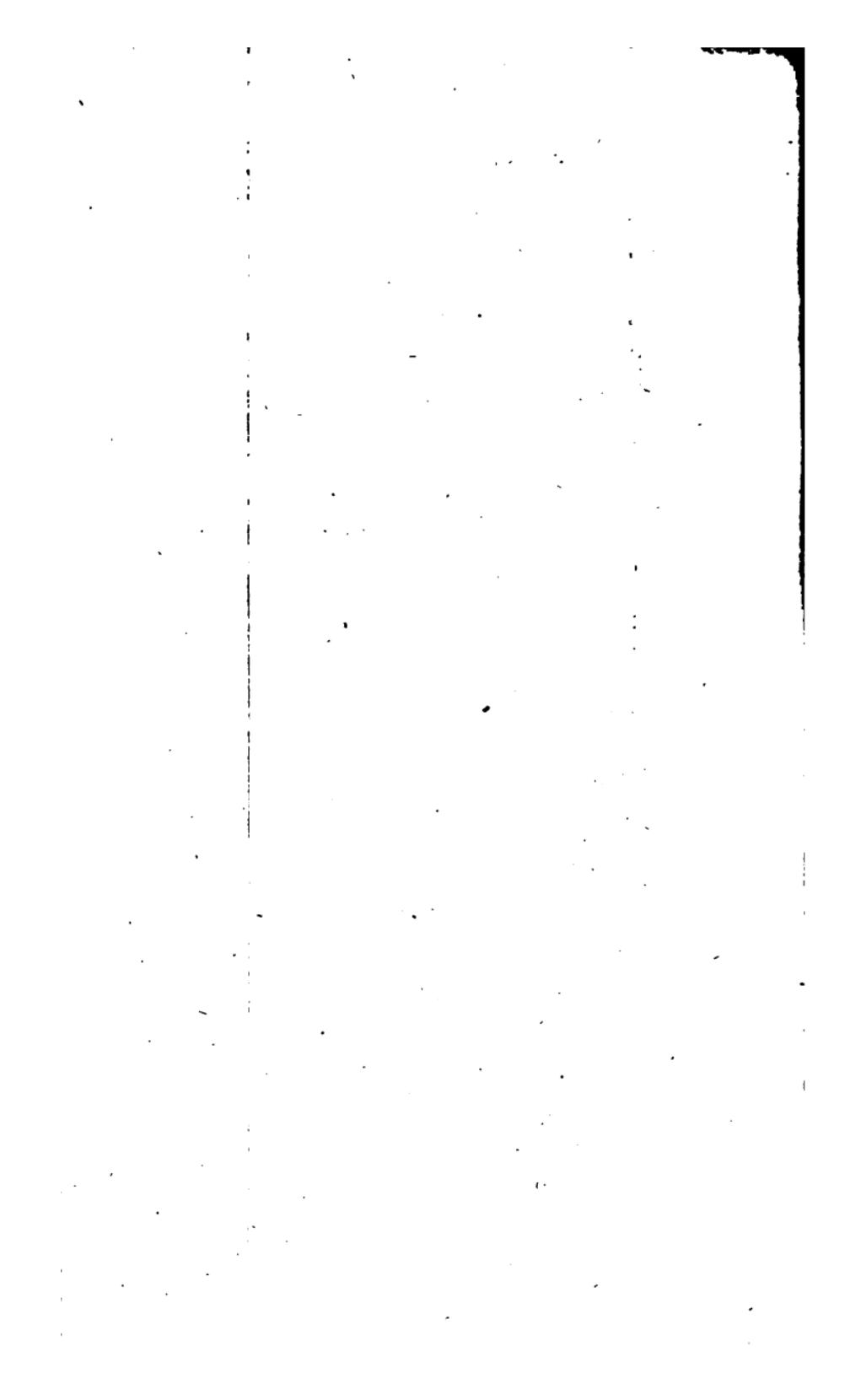
‡ Now *Melita*.

** Now *Majors*, *Minorca*, and *Ivica*.

N

Significant in the Phenician
and Italy.





at that Time by the Name of *Tarsis*, or *Tartesse**. The good Wines, the Timber, the Exquisiteness of the Corn and Cattle, but above all, the Gold, the Tin, and the Silver, of which there were very copious Mines at that Time, especially towards the Source of that River †, soon drew the *Phœnicians* on these Coasts. But this was for a long Time the utmost Extent of their Voyages; they went no farther. For this it is, that in Scripture the great Ships and Fleets, designed for long Voyages, were called the *Ships of Tarbisb* †. Afterwards the *Phœnicians* took so much Courage as to pass the *Streights*, and made themselves Masters of the Island, which they named *Gadir*, and is now called *Cadiz*. It was an advantageous Harbour to them, and inaccessible to the other Nations, who had very little Skill in the Art of Navigation. It insured them the Possession of all the Riches they brought from *Phœnicia* or other Places to exchange them, and of those they had received in Return from *Bætica*. This made them give that important Place the Name it still goes by, and which signifies an *Inclosure* or *Place of Refuge*.

The *Phœnicians* did not confine their Courses to the Coasts of the *Mediterranean*. They also opened themselves the Trade of the Coasts of *Africa* and *Asia*, through the *Arabian Gulph*, which was then called the *Idumean Sea*, or the *Red Sea*, from the *Idumeans*, who inhabited the Parts adjacent, and who had taken their Name, as well as their Original, from *Esau*, who is known to have been surnamed the *Red-haired*, or *Edom*. Not that there was then any Trench or Communication through *Suez* ‡, to pass from the *Mediterranean* or the *Nile*, into the *Red Sea*. An Undertaking like this did little agree with the Simplicity of those Times; and if the Greediness of Riches had induced the *Phœnicians* to attempt it,

K 3 the

* See *Pausan.* in *Eliacis secundis.*

† Strabo quotes the following Verse of *Stesichorus*:

Ταρίσσει ταρά τηνδες ἀπίρονας ἀρίστροπος.

Towards the Source of the River *Tartesse*—Under which Silver Mines are found.

† *Psal.* xlvi. 8. and *Isa.* ii. 16.

‡ An Isthmus that joins *Africa* to *Arabia*.

the *Egyptian* Kings had not been afterwards reduced, when they undertook it, to abandon it, as they were, from the Impossibility there was of Success*. But if the *Phoenicians*, though Inhabitants of the Coasts of the *Mediterranean*, nevertheless travelled on the *Ocean* through the *Red Sea*, it is because they had, in the Ports of the latter, Correspondencies, Factories, and Ships; a Privilege which always was, and still is enjoyed in most of the Coasts of *Asia*, and indeed does much Honour to the Affability of the Eastern Nations.

It was the Pilots of *Hiram* King of *Tyre*, who about a thousand Years before Christ, and when the *Greeks* were as yet unexperienced in the Art of Navigation, taught it the *Hebrews* with Success, and were the Guides of the Fleets which *Solomon* had established in the Ports of *Eloth* and *Exion-geber* †. This wise Prince being, by the Conquests of his Father, become Master of *Idumea*, and of the farthermost Parts of the *Red Sea*, intended, indeed, to convey Wealth into his State together with Trade; but his chief Design was to banish Idleness and Beggary; in which he was imitated by his Successors the Kings of *Judah*, and particularly by *Jehoashaphat*, the most pious and most judicious of them all. The happy and flourishing State of the *Tyrians* had taught *Solomon*, that wherever Navigation is in Request; a Beggar, who has Limbs and Strength, differs nothing from a Criminal, and that there were scarce any Criminals to be punished, when a brisk and lively Marine offered them all an infallible Resource, and easy Profits.

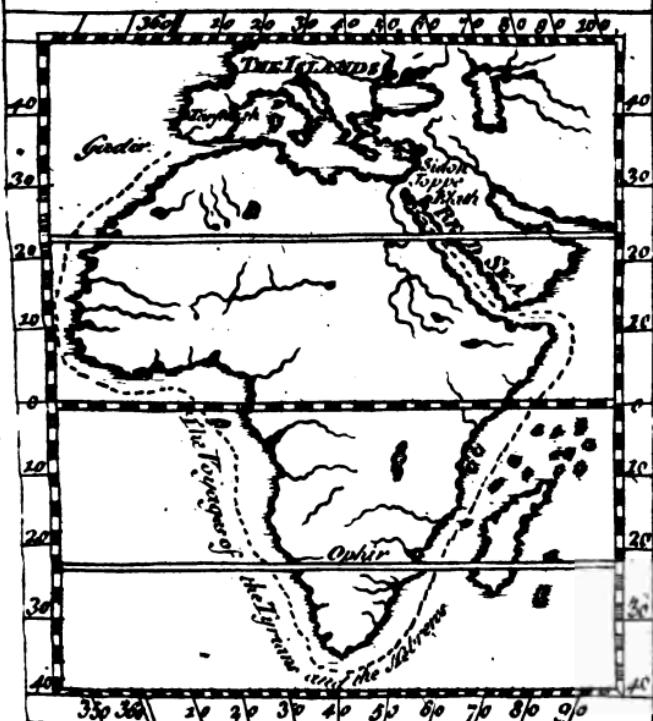
Let us now trace out our *Hebrews* in their naval Courses, and, if possible, let us find, what Parts of the Earth began to be known at that Time, by the Researches of Navigators. What Scripture tells us on that Head, amounts to the three following Facts:

1. That the *Hebrews* and *Tyrians* went together to *Ophir*, and in their Return from thence brought with them immense Sums of Gold, of precious Woods and Jewels.
2. That *Solomon's* Fleets, under Direction of the Pilots of the King of *Tyre*, made the Voyage of *Tarshish*, the Returns of which consisted in Silver, Gold, Ivory, and some

* *Herodot.* in *Melpom.*

† *1 Kings ix. 10.* *2 Chron. viii.*

THE PORT OF OPHIR *AND THE ANCIENT WAY TO TARSHISH.*





some foreign Animals, *viz.* Monkeys and Peacocks.
3. That they were three Years in making the Voyage
of Tarshish.

The first *Ophir* spoken of in Scripture*, was perhaps in the *Fortunate Arabia*, or *Arabia Felix*. *Job* and his Friend *Eliphaz* seem to have known the Brooks of *Ophir*, only because they were famous in *Arabia*, their common Country, by the Gold Sand they left in their Passage. The Name *Ophir*, already become famous, when they spoke of the Gold Sand, which the Torrents left on their Shores, was afterwards given to that Coast of *Africa* on which *Solomon's* Fleets, or the *Tyrians*, found the greatest Quantity of it. It has still the same Name and the same Trade. The Names of *Sophir* and *Sophira*, by which the Greek Translation and *Origen* † rendered the Name *Ophir*, very likely is that Coast which they call the Kingdom of *Sophara*. The *Portuguese* soften the Pronunciation of it, and call it *Sophala*. They still drive a considerable Trade there of that precious Dust which the Torrents scatter on the Coast, after having washed them from the Mines which are in Plenty in that Country, especially in the Mountains of *Manica*, whence descends the River of *Sophara*.

The *Hebrews*, who had no convenient Sea-ports in the *Mediterranean*, and would have been glad to have had a Share in the rich Trade of *Tarshish*, were told by the *Phoenicians*, that by keeping close to the Coast they would at last reach the Straights of *Cadiz*, and that there were immense Profits to be made in the Way, by exchanging some Tools of no Value, for Commodities of Consequence. Thus, with their Guides, they passed from the Country of *Sophala*, as far as the *Southern Promontory* ‡, which was long after found again by the *Portuguese*; and pursuing their Course from Coast to Coast, they kept close to the Western Shore, going up again Northward, and at last were carried to *Spain*, whence they returned not till the third Year. They began again the same Voyage every three Years, and with great

K 4

Profits,

* *Gen. x. 29. Job xxii. 24.*† In *Job xxii. 24.* *Origen* is inclined to think *Sophira* is in *Africa*.‡ *The Cape of Good Hope.*

Profits traded in *Spain*, and all along the Coasts of *Africa*, as they went backwards and forwards.

Several learned Men place *Tarbis* and *Opbir* in the Island *Ceylon*, or in the Peninsula of *Indus*. But our Navigators, by coasting along the Shores, as they then did, might a few Months after have reached the Cape, which terminates the Peninsula of *Indus*. Besides, it is known by unquestionable Proofs, that the Country of *Tarbis* was the *Bætica*, or *Spain* in general; and *Jonas* would never have embarked at the Port of *Toppa* in the *Mediterranean Sea*, to take his Flight to *Tarbis* towards the West, if that Country had been in the Eastern Ocean. Hence therefore we may judge, that both the *Hebrews* and the *Phœnicians* went round the Continent of *Africa*, to join the Trade of all its Coasts to that of *Bætica*; as is plainly proved by the three Years Time, employed in getting back again into the Port of *Elob*; and this Proof is still supported by the Nature of the Commodities they brought with them. These were Metals, which they had drawn from *Spain* and *Opbir*; Ivory, which they fetched from the Coasts of Teeth, where Elephants are more common than in any other Place; Monkeys and Peacocks, all Animals easy to be found on the Coasts of *Africa*; and finally, precious Woods and Jewels. They might find on the Coast of *Africa*, a great Quantity of yellow Amber, of red Coral, Coral of other Colours, and of very fine Jasper, of which they still carry on the Trade in the Kingdom of *Beniz*, and several other precious Stones, which are found in the inner Part of the Country. In their Return, they might, without any Cost, cut and shape the finest Sorts of Ebony, and the other Woods used for inlaid Works, in the Forests of *Madagascar* and *Mosambique*, which are still full of them on the Eastern Coast. They also found some other precious Woods, by touching on the Coasts of *Felix Arabia*, after they had passed the Straights of *Babelmandel*, which is the Entrance of the *Red Sea*.

This Commerce was afterwards interrupted, and that Way abandoned: Not on Account of the Failure of the Mines of *Andalufia*, which were not exhausted till the *Romans* had them; but by the Decay of the *Jews* and *Tyrians*, whose Trade and Commerce the Kings of *Babylon* endeavoured

endeavoured to ruin, before they undertook to destroy their Cities. However, though the Conquests of these ambitious Monarchs, by including *Idumea* and all the Ports of the *Red Sea*, had sunk the Commerce of *Tarshish*, that is, the Voyage of *Cadiz* by the long Circuit of *Africa*, they did not so soon lose the Remembrance of that Course: They knew it very well at the Court of *Necao*, who reigned in *Egypt* six hundred Years before Christ. That Prince, who had a Mind to restore the antient Splendor of his Kingdom, with great Reason thought he could never succeed in it, otherwise than by the Re-establishment of Navigation. In order to which he undertook the Junction of the Ocean with the *Mediterranean*, by making a Trench that was to reach from the *Nile* to the *Red Sea*. "But afterwards (these are *Herodotus's* own Words) having intirely abandoned the Execution of that Canal, he caused some *Phoenicians* to embark on the *Red Sea*, and ordered them to go round *Africa*, to leave the Streights of *Hercules*, to penetrate even as far as the Northern Sea, and to come again and give him an Account of it."

The *Phoenicians* (being, from the Accounts of their Fathers, perfectly well acquainted both with the Way thither, and the Method of living there, without over-loading themselves with large Stores of Provisions) set sail from the *Arabian Gulph*, and advanced forward into the South Seas: And not being ignorant that the Summer Rains destroy, in the Midst of *Africa*, what has been sowed in the Spring, "in Autumn they landed, sowed their Corn, and staid for the Time of Harvest, without leaving the Coasts of *Lybia*: They then gathered their Crop, and got to their Ships again. After two Year's Navigation, they arrived at the Columns of *Hercules*, and passing the Streights, came back again the third Year to *Egypt* through the *Mediterranean*."

From this Recital it is plain, that nothing was then better known than the Circuit of *Africa*, and the Voyage of *Cadiz* through the *Red Sea*. The Intention of *Necao* was not to inform himself of the Possibility of that Course for the Good of his Commerce: In his Instructions to the Pilots, he supposes them to be fully acquainted with it: But his Intention was, that they should do something more

than what was done by going through the *Red Sea* to the *Column of Hercules*, and try to penetrate into the Northern Sea, which very likely began to be talked of; and to inform him, whether there might be some useful Discovery made, or any Trade to be established on that Side. It was without any Necessity then, that the learned *Boccart*, who had so ingeniously demonstrated the Situation of the antient *Tarshish* in *Bætica*, and near the Streights of *Cadiz*, imagines another *Tarshish* in the East, thinking the Voyage round *Africa* to be then impracticable.

A little Particularity related at that Time to King *Necao*, by his Navigators, puts the last Hand to the clearing this Point of History. At Noon the Shadow of our Bodies is always cast towards the North, and when at that Time we look Westward, we have the Sun on our Left. Our *Phœnicians*, on the contrary, being arrived on the Extremities of *Lybia*, saw the Shadow of their Bodies at Noon thrown to the South. They then told the *Egyptians*, that in their going towards the West, they had the Sun on their Right. The *Egyptians*, who were not by far so good Astronomers as they are supposed to have been, recounted this Fact as a wondrous Thing; and *Herodotus*, who heard of it in their Country, about a hundred Years after the Event, refused to give Credit to the Account that was given of it to him. But what surprized him so much at that Time, is the very Demonstration of the Matter of Fact, and clears the Account given by the Navigators. It is now universally known, that the Sun keeping his several annual Situations, within the Tropics, we on either Side perceive two different Projections of the Shadows: Those on this Side the Tropic of *Cancer* see the Sun on their Left as they look to the West, and their Shadow is extended towards the North. On the other Side the Tropic of *Capricorn*, it is just the Reverse. The Shadow flies to the South, and they have the Sun on their Right as they look to the West. This Particularity, so contrary to the Prejudices of the Antients, and on the other Hand the Return of the *Phœnicians* through the Mouth of the *Nile*, after they had begun their Voyage by the *Red Sea*, are a sufficient Demonstration of the Knowledge they then had

had of the Circuit of *Africa*. These Voyages, which were afterwards discontinued for above two thousand Years together, and of which the *Portuguese*, two or three Centuries ago, thought themselves the first Authors, were very common in the Time of *Solomon*, and under his Successors.

You see, Sir, that it is to the *Phoenicians* that we are beholden for the first Knowledge, both of the Coasts of the Ocean, and of those of the *Mediterranean*. They every where make their Way, by their constant Attention to the Advices of the Polar Star. Geography begins to come to some Shape: Nations emerge from their Obscurity: They draw again towards each other, after the long Distance they had kept from one another since the Time of their Dispersion. After having each of them improved the Qualities of their Land, and the Aspect of their Heaven, they begin to communicate the Fruit of their Works, and to afford mutual Helps to each other. Societies are formed; and all these happy Novelties are the Consequence of the Observation of a Star.

THE
 DISCOVERY
 OF THE
 ROUNDNESS
 OF THE
 EARTH.

The New Progress of GEOGRAPHY.

DIALOGUE III.

THALES was not contented with having taught the Greeks the Advantages resulting to Navigation from the Knowledge of the Polar Star: He determined for them the whole Series of Stars, under which the Sun is successively found within the Compass of a Year. He afterwards, with the same Care, observed all those under which the Moon passes within the Revolution of a Month. He soon found, that the Moon does not exactly place itself under the same Stars as the Sun; but that the Orbit or Series of Stars it runs under in a Month's Time, cuts the Orbit of the Sun in two Points; and deviates a little from it on either Side. He then took Notice, that the Points, where these two Orbits cut each other, were not always the same from one Month to another, and that the Intersection

section of them happened sometimes under one Star, sometimes another; but that these Variations, after a certain Number of Revolutions, began anew, and were again very nearly the same. He was, or at least ought to have been then, sensible of the Intention of a benevolent Providence, which, by thus making the Orbit of the Moon cross that of the Sun, had taken Care that these great Flambeaux were not eclipsed every Fortnight, when the Moon is in its Full, or in its Opposition to the Sun, should be obscured by the exact Interposition of the Earth in the same Line; or when the Moon in Conjunction, that is, placed between the Sun and the Earth, should take all Light from the latter. He apprehended, that the Intersection of the Orbits, and the Variations of the Points of Section, were Means wonderfully managed and prepared, to render the exact Union of these three Bodies in one and the same Line much more rare. But having gradually observed, that these Variations of the Moon were limited, that it began anew the same Changes of its Place, and was in its apparent Irregularities, tied up to a fixed Rule, as well as every other Part of Nature; he watched all the different Courses of this nightly Star, and compared a sufficient Number of them, to make himself certain of the Day on which the three great Bodies should be in the same Line, and screen each other. He then came to foretel Eclipses; and the Nations, whom these Events used to terrify, took Heart again, when they heard that the so sudden darkening of these Stars, the Cause whereof they had so long been unacquainted with, was the necessary Result of their mutual Interposition, and of the wise Laws, according to which they revolved for the Service of Mankind.

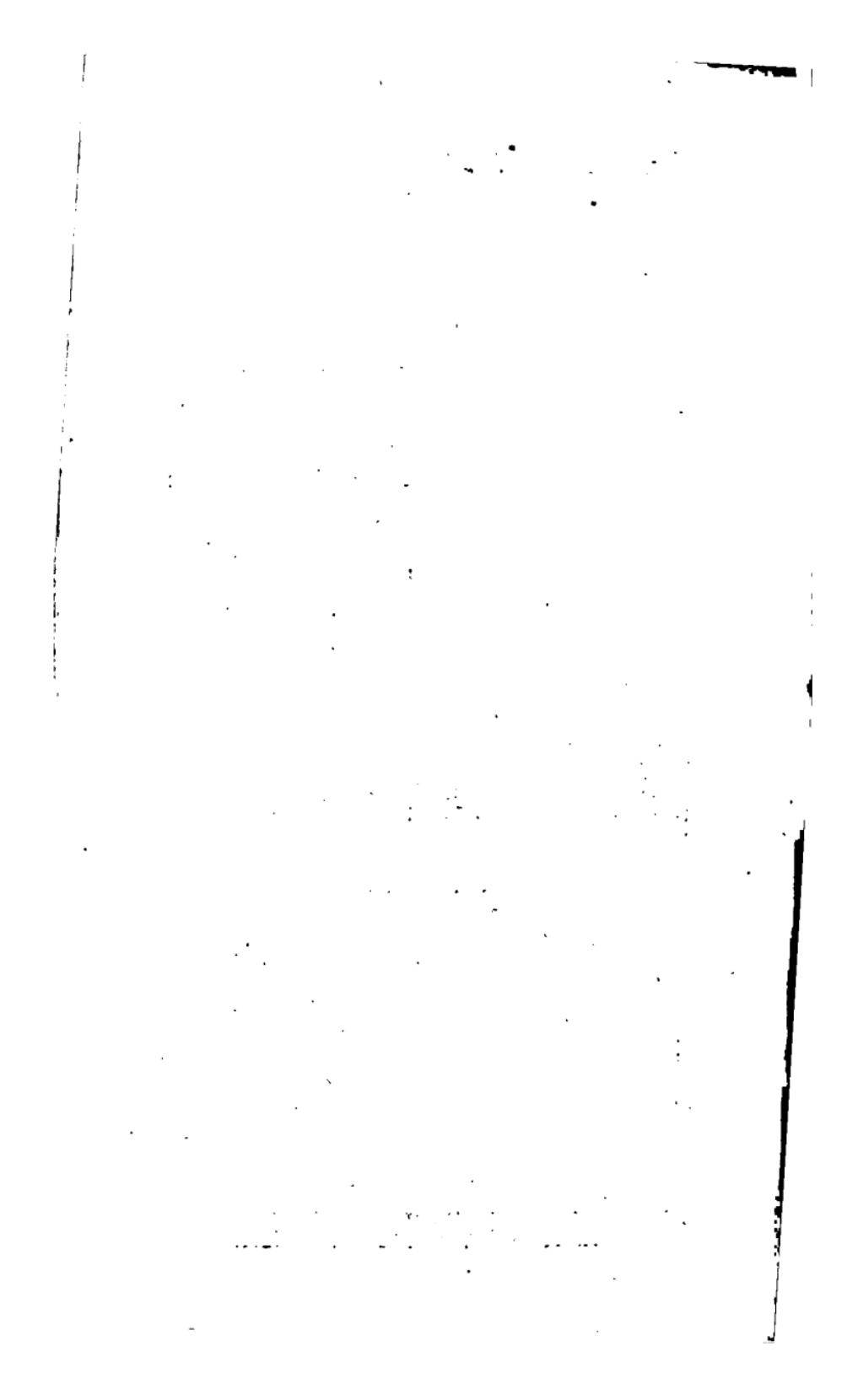
The chief Benefit of the Knowledge of Eclipses was not only to quiet, by the Prediction made of them, such Minds as might have been terrified by them: Geography found also its Advantage in that Discovery, and the lunar Eclipse more particularly served to give more just Measures of the Distance of one Country to another. At the Approach of that Eclipse, two Observers being placed, one at *Milet*, the other at *Babylon* or *Syracuse*, mutually agreed strictly to observe the Hour and exact Instant of the Moon's

Geographical
Measures.

Moon's entering into the Shadow of the Earth, then the Hour of its greatest Obscuration, and finally the Instant of its total Emerion from the Shadow. As they were sure, that when the Moon is obscured with regard to one Nation, it is so with regard to all the rest; because it is eclipsed only on Account of its being deprived of the borrowed Light which makes it visible; they put their Observations together, in order to compare the Difference between the Hour reckoned by one of the Observers, and that marked out by the other. As it was easy for them to know the exact Distance that was between two Cities equally distant from the *Æquator*, and one of which had the Sun an Hour sooner than the other, when they saw, that there was a Difference of so many Hours between the Instant of the Eclipse at *Babylon*, and the Instant of the same Eclipse seen for Instance at *Syracuse*; they thence concluded, that *Babylon* was by so many Hours more to the East, and consequently, that there was such a Distance from *Babylon* to *Syracuse*. It must be owned that the Facility we now have of measuring Time in a uniform Manner with our Pendulums, has rendered these Observations much more exact among us: But the Glory of our Exactness and our Progress may be carried back as far as *Thales*. We make use of what he has discovered: And if we were to determine to whom we were most obliged, he who first foretold the Return of Eclipses, or he who substituted Pendulums to our Balance-clocks, it might be Matter of mature Deliberation.

Another Advantage, that sprung from The Roundness of the Earth, the Observation of lunar Eclipses, was the Certainty of the Roundness of the Earth, not very well known before that Time. The Eastern Nations gave the Earth the Name of *Tebel*, whence came our Word *Table*; because it was indeed an universal Prejudice, that the Earth was a flat Surface terminated by an Abyss of Water. The Poets favoured this Prejudice, by always speaking of the Rising and Setting of the Stars, as if they came out of the Bottom of the Ocean in the Morning, and went thither again to cool themselves at Night. A poor Philosophy, and pitiful Jargon! which our Poets are still as fond of, as they are of the Rubbish of Paganism: As if it were not as meritorious





meritorious to represent Nature in its Beauty, as to paint imaginary Tribes. The *Ionian* School shook off these Prejudices: They not only understood, that the Moon shone with only a borrowed Light, and that it was obscured by the exact Interposition of the Mass of the Earth between the Moon and the Sun; but judging besides of the Figure of the Earth, by that of the terrestrial Shadow, which gradually was thrown upon the Disk of the Moon, they could no longer doubt of the Roundness of the Earth.

Anaximander, and the other Successors of *Thales*, persevering in this reasonable and useful Kind of Study, began to collect the Histories of famous Expeditions, the Accounts of Travellers, and the Memoirs of Pilots, and to compare the whole with their Observations. They presumed to give the Descriptions, Figures, Distances, and Relations of the known Countries. According to some of the Learned, the Philosophers of the *Ionic* Sect collected all these particular Branches of Knowledge in one Sphere or System, and for the first Time shewed *Greece* a terrestrial Globe. According to some others, they only produced geographical Maps, and local Descriptions.

We may suppose, that Geography was as yet very imperfect, and that Falshood did every where disfigure Truth therein: But it was no small Point gained to have begun; and ever since that Time, Emulation, the Love of Sciences, Mathematics, Commerce, and Navigation, went on Hand in Hand, and always increasing among the Greeks. They became as famous by their Colonies, as the *Tyrians* were. *Syracuse* in *Sicily*, *Marseille* on the Coast of *Gaul*, *Cyrene* in *Africa*, and *Naukratis* in *Egypt*, are not the least of their Establishments. They maintained the Liberty of the *Eolians* and *Ionians* their Brethren, who were often troubled in *Asia* by the Covetousness of the Ministers of the Kings of *Perse*. They kept the Sea, in spite of the numerous Fleets of that formidable Empire: They at last destroyed it, and were beholden for these good Successes to their Education and Knowledge, rather than to their Forces, which were no Way comparable to those of the *Asiatic* Monarchy.

The

The Conquests of *Alexander*, which changed the whole Face of the Universe, gave Sciences quite a new Form. That Prince, as fond of Learning as he was brave, and full of the noble Ideas which his Master *Aristotle* had inspired him with, had always about him learned Men, who were appointed to collect for him the Distances of Places, the several Particulars of Natural History, and all the Observations made by the Nations whose Provinces he marched over. And after having so often endangered his Life, to free *Greece* from the Yoke and Vexation of the *Perians*, he exposed himself, merely to make the Discovery of some new Countries *. He went as far as the *Indian* Ocean, and had like to have been carried away with his whole Army, by the Rapidity of the Tide, with which he was not at all acquainted. His Rashness every where succeeded. Astronomy, Geography, and History, gained extremely by it; and though his Empire was divided almost as soon as it was formed, his Successors, the Posterity of *Lagis* in *Egypt*, that of *Seleucus* in *Syria*, and the others who divided *Asia Minor* and *Macedonia*, being originally *Greeks*, the *Greek* Tongue became an universal Language, a trading Tongue which settled a mutual Correspondence among all the Nations of the three Parts of the antient World. The Western Nations began to know the Riches, the Productions, the Customs, and the History of *Asia*. It is true, the *Greek* Philosophers had not taught Men the wholesome Truths of Religion. But by thus exciting a general Curiosity, and an Eagerness for Instruction, they insensibly prepared all the Nations of the Earth for the Reception of a Doctrine much more enlightened, and a ready Submission to the Precepts of the Gospel.

Of all the Successors of *Alexander*, none did more Service to Astronomy than the *Lagid* Kings. The Wishes and Inclinations of great Kings are always efficacious, and they soon see those Branches of Learning flourish which they think fit to reward. The *Ptolemies* judging nothing to be more worthy their Favours than the Works of Astronomers, *Alexandria*, their Capital, became

* *Quint. Curt.* 1. ix. c. 6.

became the School of that Science. *Conon*, *Aristides*, *Timocbaris*, and many others, were very eminent that Way, and made Observations useful to Navigation. *Eratosthenes*, Keeper of the Library of *Alexandria*, in the Reign of *Ptolemy Euergetes*, undertook to calculate the Number of Stades, (or Measures of 125 Paces long) that might make up the Circuit of our Globe; and he had the Glory of coming near the Truth. He knew, that at the Summer Solstice the Sun passed through the vertical Point of the City of *Sienna*, being on the Confines of *Egypt* and *Ethiopia*, under the Tropic of *Cancer*. There was at *Sienna* a Well made on Purpose for that Observation, which about Noon, on the Day of the Solstice, was wholly enlightened within by the Sun perpendicularly over it *. It was a well known Fact, that at 150 Stades round about, Styles raised perpendicularly on the horizontal Surface projected no Manner of Shadow †. Having supposed *Alexandria* and *Sienna* to be pretty near under the same Meridian, that is, in one and the same Line drawn from Pole to Pole, he observed in *Alexandria*, on the Day of the Solstice, the Distance of the Sun from the vertical Point, by the Shadow of a Style raised perpendicularly on the Bottom of a half concave Sphere, and pointing out, by its upper Extremity, the Center of the Sphere of which it was the Radius. Had that Needle projected no Shadow, it would have been because the Sun was perpendicularly over that Place. He then could judge of the Distance of the Sun from the vertical Point, by the Distance of the Top of the Shadow from the Foot of the Needle. He found that Distance was the fiftieth Part of the Circumference of an intire Circle; whence he concluded, that as the Sun, at that Time perpendicular over the City of *Sienna*, was distant from the vertical Point of *Alexandria*, by the fiftieth Part of the Circumference of the whole Heaven; *Alexandria* was distant from *Sienna* by the fiftieth Part of the Circumference of the whole Earth. Now it was an easy Matter, to know the Distance that was between these two Cities, and to repeat it fifty Times. Having then calculated that Distance

* *Plin. l. ii. c. 63.*

† *Umbra non quam scilicet Syene. Phars. l. ii. v. 527.*

Distance to be 5000 Stades, he found that the Circumference of the Earth was 250,000 Stades, which being reduced into common Leagues of 24 Stades each, made 10,416 Leagues and 16 Stades. This came very near the Computation of the Moderns: According to which, the Circuit of the Earth is judged to be somewhat more than 9000 common Leagues.

Hipparchus, a great Observer of the same School, distinguished 1022 Stars, and gave each of them a particular Name.

While the *Greeks* were making this great Progress in the Study of Nature, the *Gauls*, our Fathers, did not neglect it, and their *Druids* had at least some common Notions of it, which they communicated *viva voce* and unwritten to their Disciples, to oblige them to know more certainly the Things which, in Time of Need, they could find no where but in their Memory. But the Inhabitants of *Marseilles* having been for a long Time Masters of a very flourishing Trade, and being desirous to extend it in the Ocean, as well as in the *Mediterranean*, they encouraged by Rewards such astronomical Observations as might assist their Navigation, and, by making them a Way to new Countries, afford them new Means of gathering Riches. In the very Time of *Alexander*, *Pytheas* had raised a Gnomon in *Marseilles*, and measuring the Length of the Shadow at the Day of the Solstice, and then comparing it with the Height of the Gnomon, he determined how far the Sun was distant from the Zenith of *Marseilles*, and consequently how far that City was distant from the Tropic and the *Æquator*. He found, that on the Day of the Solstice the Length of the Shadow of a Needle is to the Height of the Needle itself, what 41 is to 120; a Proportion which *Mr. Gaffendi* found again to be the same at *Marseilles*, above two thousand Years after the first Observation*. *Pytheas*, the better to serve his Country, undertook to traverse the whole *Mediterranean* to the very Bottom of the Lake *Mæotis*, where the River *Tanaïs* discharges itself. He afterwards ventured to advance through the Ocean to the very Bottom of the North. He observed along the Coasts (very likely of *Norway*)

that

* In the Year 1636.

that towards the Summer Solstice the Sun remained but three Hours under the Horizon, and that as he advanced so far as the Island *Thule*, which can be no other but *Iceland*, or *Lapland*, he saw the Sun disappear for an Instant, and immediately after re-ascend the Horizon. When we treat of the Sphere, you will see, that the Sun, describing the Line of the Tropic on the Day of the Solstice, of Necessity must be seen four and twenty Hours together, or hide himself only for an Instant behind the Mountains that bound the Horizon, in those Countries where the Tropic is wholly in the visible Hemisphere, and just touches the Horizon with its lower Extremity. In this, *Pytheas* advanced nothing but what was exactly true. Experience agrees with him; and the Geographers of *Alexandria*, who were sensible of the Conformity of this Relation with their Principles, did not fail to make use of it, to distinguish Climates and the Diversity of the Days from one Climate to another.

Pytheas had still indeed many Prejudices as to the Structure of the World, which, together with some certain Appearances, contributed to deceive him. He was ignorant of the Rotundity of the Earth, and among other false Notions which he entertained concerning the Disposition and Situation of the Northern Countries, he thought he saw very distinctly the Heaven supported by the Earth, like an inclined Arch, and forming at its Extremities a very long Angle, where People were straitly confined, and obliged to stoop. *Strabo*, the most judicious of the ancient Geographers, was much in the right, when he exploded Accounts like these. But he himself is much mistaken, not only when he thinks the Northern Countries uninhabitable, but also when he treats as Fables the Observation of the Height of the Solstice at *Marseille*, and the Discovery of the perpetual Decrease of Night, as we advance in the North, at the Approach of the Summer Solstice: Which shews, that *Strabo*, who was acquainted with the Roundness of the Earth, and the Inequality of the Declinations of the Sun, did not himself draw proper Consequences from them. The Testimony of all Navigators is in Favour of *Pytheas*, and he is the first who caused Men to use the proper Cautions towards regulating the important Navigation of the North, by informing us

of the Advantages of going thither in the Spring, and of preventing the Return of the Ice, and of the long Nights, which could never be avoided, should we expose ourselves thereto at the Approach of Autumn.

If we pass on from the Knowledge of Physics among the *Gauls* to that of the *Romans*, we shall

find, that military Discipline and Politics were long their only Philosophy. But when they had once tasted the Arts and Sciences of the *Greeks*, they applied themselves much less to Physics and to Experiments, which are always long and toilsome, than to Questions of mere Speculation; because these exercised their Minds without tiring them, and gave them an Opportunity of shewing, at little Expence, some Learning, and a polite Style *. Let us do many of them Justice. They often looked in the Improvement of their Reason for Means of Employment, and for Comfort in their Troubles. But, generally speaking, the Curiosity was overpowered by Idleness. Physics and Astronomy met with but very few Favourers amongst them. Necessity rather than Inclination rendered *Scipio*, *Pompey*, and *Julius Cæsar*, favourable to these noble Sciences. These great Men, always taken up with Projects, and busied about Voyages and Conquests, were fully sensible of the Value of the Knowledge of Times, Places, and Distances. *Scipio Africanus* for a long while employed *Polybius*, in running over the Coast of the *Mediterranean*, in order to write for him exact Memoirs. *Pompey* kept an epistolary Correspondence with the Astronomer *Ptolemy*, who had more particularly applied himself to calculating how many Miles a Degree of the Circuit of the Earth contained, and to the measuring of that Circuit by the known Distances of some select Towns placed under the same Meridian, or under a Line drawn from North to South, in order to judge of the Whole by a Part.

Julius Cæsar, who had early applied himself to these particular Branches of Learning, and knew how to be successively a Warrior, an Orator, a Pilot, and a Carpenter, was likewise one of the most learned Geographers

of

* See *Tully's Philosophical Works*.

of his Time. He was become so by his perpetual Voyages, by the instructive Memoirs he caused to be sent to him from all Parts, and chiefly, by the Care he took to judge of every Thing himself, and to keep a faithful Journal. We see him passing into Great-Britain with Water-clocks, in order to have an uniform Measure, to shew him exactly the Difference between the Length of Nights in Britain, and of those in Gaul. He found the former shorter toward the Solstice; and he may be said to have been a very great Naturalist, as he was a great Observer.

In order to make himself a good Geographer, he could not help being an Astronomer. On this is grounded the Discourse which *Lucan* causes him to address to one of his Priests, from whom he hoped to learn the Origin of the Overflowing of the *Nile*. "In the Midst of my military Expeditions, saith *Cæsar* to him, I always gave a few spare Hours to the Observation of the Course of the Stars, to the several Aspects of the Heaven, and the Knowledge of celestial Things. I even dare to hope, that *Eudoxus* * will not for the future be more famous by the *Ephemerides* he gave to *Greece* at his Return from *Egypt*, than I shall be by the Order to which I have reduced the Course of the Year †."

And indeed, no body is ignorant of the Care he took, to render the Method of computing the Year more agreeable to the exact Duration of the annual Course of the Sun. The Years, measured according to his Calculation, are for that Reason called *Julian* ‡; and in Acknowledgment of this useful Reformation, his Name was given to one of the Months of the Year. *Augustus* || obtained the same Honour, for having facilitated the Study of the several Elevations of the Sun, by Means of the Shadow of an Obelisk 111 Feet high, which he caused to be erected in the Field of *Mars* §, and for having caused the Account of the Lengths of all the Coasts

* A Disciple of *Plato*.

† ————— *Media inter prælia, semper*
Stellarum, earlique plagi, superisque vacavi;
Nec mens Eudoxi vincetur saſibus Annus.

Pharsal. l. x.

‡ The Month of *July*.

§ The Month of *August*.

¶ *Plin. Hisf.* l. iii.

Coasts and Roads of the Empire, drawn up from the Memoirs of his Son-in-law *Agrippa*, to be registered in a Portico built for that Purpose.

But the two most learned Men in this Kind, that ever lived under the *Roman* Emperors, are *Pliny* the Naturalist, and *Ptolemy* of *Alexandria*, the one a hundred *, and the other one hundred and fifty Years † after Christ; both very great Geographers: The latter however was a better Astronomer than a Geographer.

Pliny, disgusted with the Philosophy of the Schools, on Account of the Futility of the Matters there treated of, and the unbecoming Manner of perpetual Wranglings which reigned there, formed the Project of collecting useful Branches of Learning, fit both to adorn the Mind, and enrich Mankind. He gathered therefore all he could on those Subjects, which naturally ought to employ the Mind of Man, such as are the general Order of the Heaven, the Description of the Earth, or of the known Countries, the Birth and Education of Man, the Invention and Progress of Arts, the terrestrial Animals, the aquatic, the amphibious, the Birds, the Insects, the foreign Trees, the odorous Spices, the Fruit and Forest-trees, the Culture of Plants, the several Kinds of Corn, Husbandry, the Uses of Flax, Gardening, medicinal Plants, Flowers, Botanics, Physic, Metals, metalline and coloured Earths, Stones, and Jewels: This is his whole Book. It was hardly possible to make a more judicious Choice.

It must be owned, that *Pliny* received what was told him with too much Easiness; that he would have served us to better Purpose, had he made Criticism and Experiments go Hand in Hand with his Researches; that in short, the Style of his Work, though full of Sublimity and Fire, every where has a Touch of the Fault which corrupted Eloquence at that Time, and which will always corrupt it in every Age, I mean the Itch of being witty. But that Book, with all its Faults, is nevertheless a Treasure. If Teachers had a Mind to acquaint themselves with *Pliny*'s Mistakes, they might, by shewing them in Parts to their Disciples, be as useful as if

Pliny

* Under *Domitian*.

† Under *Marcus Aurelius*.

Pliny had told the Truth every where; and together with the richest Stock of all the Terms of the *Latin Tongue*, convey into the Minds of Youth such Branches of Learning, as are most fit to adorn and afford them Employment for the rest of their Lives.

Claudius Ptolemy, a Disciple of the School of *Alexandria*, procured himself an immortal Reputation, by his excellent Book, intitled, *Of the great Construction of Planets and Stars*; which we also call *Almageste*, after the Translation which the *Arabians* every where spread of it in the ninth Century. Having compiled the Opinions of *Aristotle*, *Hipparchus*, and *Posidonius*, on the *Œconomy of the World*, adding his peculiar Opinions thereto, he pretended that the Earth was in the Center of the World; that there were as many concentric Heavens as Planets; that the first Heaven, which encompassed the Earth, was that of the Moon; that the next Heavens were those of *Mercury* and *Venus*, then that of the *Sun*, next to which were those of *Mars*, *Jupiter*, and *Saturn*: That all these Heavens were encompassed by that of the fixed Stars; that this last dragged the whole away every four and twenty four Hours from East to West; but that while each of these Heavens was thus hurried away by the starry Heaven, or by the daily Revolution of a *Primum Mobile* imagined above the starry Heaven, they had each of them in particular a peculiar Motion, by which they made just the opposite Revolution from West to East round the Earth, some in a few Months, the Sun in a Year, and the other in several Years. Some other Astronomers, having observed more Motions still, multiplied the Heavens as they pleased, to account for these Appearances, and thought they had found good Reasons to inclose, one within another, even seventy Spheres concentric to the Earth.

We must own, that this Contrivance of *Ptolemy*, together with all the Additions of After-times, proves absolutely unwarrantable, and we soon shall see what Experience thought fit to reform in it. However, it is a great Point gained, to have found, as *Ptolemy* did, mathematical Instruments of a determined and certain Utility, and to have imagined in the Heaven, an Order, which, false as it was, yet in many Respects enabled the Observers to

give a probable Account of the Motions of the Sun and Moon, to foretel Eclipses, and to improve Geography by certain Rules.

This last Use is that which *Ptolemy* himself made of his Astronomy. He made use, as much as possible, of the known Distances of some certain Stars, the Elevations of the Pole above the Horizon of several Places, and the Comparison of the Distances known on the Earth, with a certain Number of Degrees on the celestial Sphere, to determine by how much the most famous Cities were distant from the *Æquator*, which is called their Latitude; or by how much one is more to the East, than another, which is called Longitude; in short, to make Maps infinitely better than those before him. *Hipparchus* had been reformed by *Posidonius*, who lived a little before Christ: *Posidonius*'s Maps were reformed by *Marin of Thyr*, who lived towards the Middle of the first Age of the Christian *Æra*: Those of *Marin of Thyr* were reformed by *Ptolemy*. But if we now find Fault with the Maps of *Messieurs Jaiilot and De l'Isle*, who rectified so many Mistakes in the Maps and Globes composed before them, we must not be surprized at the Faults of which *Ptolemy*'s Maps are full.

He knew very well how to observe, and make a proper Use of his Observations: But he could neither be every where, or have every where Correspondencies. As most of his Calculations were grounded on popular Measures, commonly taken without Exactness, or Regard to the Obliquities and Crookedness of Ways and Grounds; it is easy to guess to how many Mistakes his Calculations are subject. In his Time they knew but little of the Northern and Southern Regions, which they thought uninhabitable: Which is the Reason why the terrestrial Distances that Way were called Latitude, whereas they called Longitude the Degrees of Distance from the occidental Border of *Africa* towards the East, because they knew many more Countries that Way than from North to South. His Maps, which were for a long while the only ones used by Warriors, Seamen, and Virtuosoes, have led Readers into numberless Mistakes; *Africa*, for Instance, is there continued of one Breadth much beyond the Equinoctal Line, for Want of

PTOLEMY'S



The coasts of the Countries as Ptolemy knew
coasts such as we actually know them are expt
Taprobana, is much Smaller and is drawn
ends at the 140th degree of Longit. is 500 leagues
other Hemisphere.

formations on the Contraction of that large Peninsula towards the *Cape of Good Hope*. Nay, this made several of the Learned affirm, that *Africa* formerly was joined to *America*, and that they had been disjoined by Earthquake. This Pretension is overthrown by what *Herodotus* taught us of the Voyage that was most commonly made of old, from the *Red Sea* to the *Herculean Columns*.

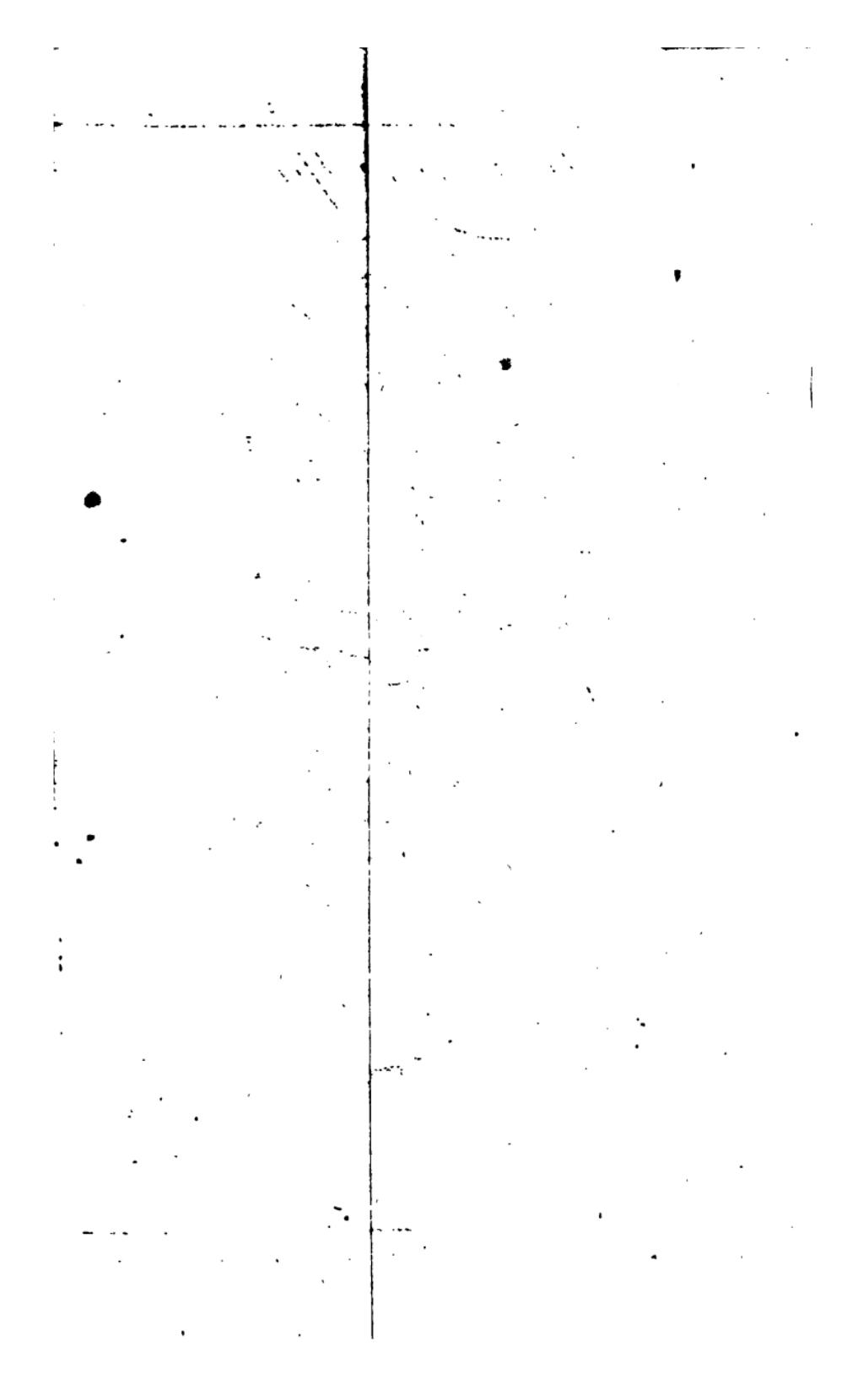
Ptolemy does likewise place the Country of the *Seres*, and the other Parts of *Asia*, at much too great a Distance towards the East; and we shall afterwards see, that this was the Occasion of the happy Mistake of *Christopher Columbus*, who looking for *China* towards the West, on the Testimony of *Ptolemy's* Maps, found *America*, which he had not the least Suspicion of.

But instead of being particular with regard to the Progress of Geography, I have contented myself, my dear Chevalier, here to give you a little Map of the World, as it was antiently known, and compared with the modern one. The latter I have marked by very small Lines or Strokes in the Map. The Borders of such Countries, as were yet either unknown or little frequented, I have left undetermined; and you will there find the whole Southern Part of *Africa* sunk again into its former Darkness, by the discontinuing of the ancient Commerce of *Tarsish* through the *Red Sea*.

THE INVENTION OF THE GLOBES.

DIALOGUE IV.

THE Ionian School, founded by *Thales* at *Miletum*, having had the first Ideas of the Rotundity of the Earth, seems to have first delineated the Representations of it. We know not, precisely, who was the Inventor of the Globes, one of which represents the Heaven, and the other the Earth, nor to whom we are indebted for the hollow Sphere made up of Circles, so cut as that they may be seen through, and fit to express the apparent Motions of the celestial Bodies. These Contrivances, very rough and imperfect in their Beginning, were improved by Degrees. *Hipparchus* and *Archimedes* of *Syracuse*, about 200 Years before Christ, *Posidonius* somewhat more than 50 Years before the same Period, and *Ptolemy* about 140 Years after, are the Men, who by the Assistance of Geometry and Observations contributed most to render the Service of Spheres certain and exact, by making it agree with the Aspect of the Heaven, and the Motions of the Stars. We may sufficiently inform ourselves of the Mistakes of these great Men, especially of the last, with regard to the Situation and Course of the Planets, when we come to the Experiments of latter Ages. But their Work having long been the chief Rule of the Study of the Heavens, and still serving in a plain Manner to account for



Spheres.

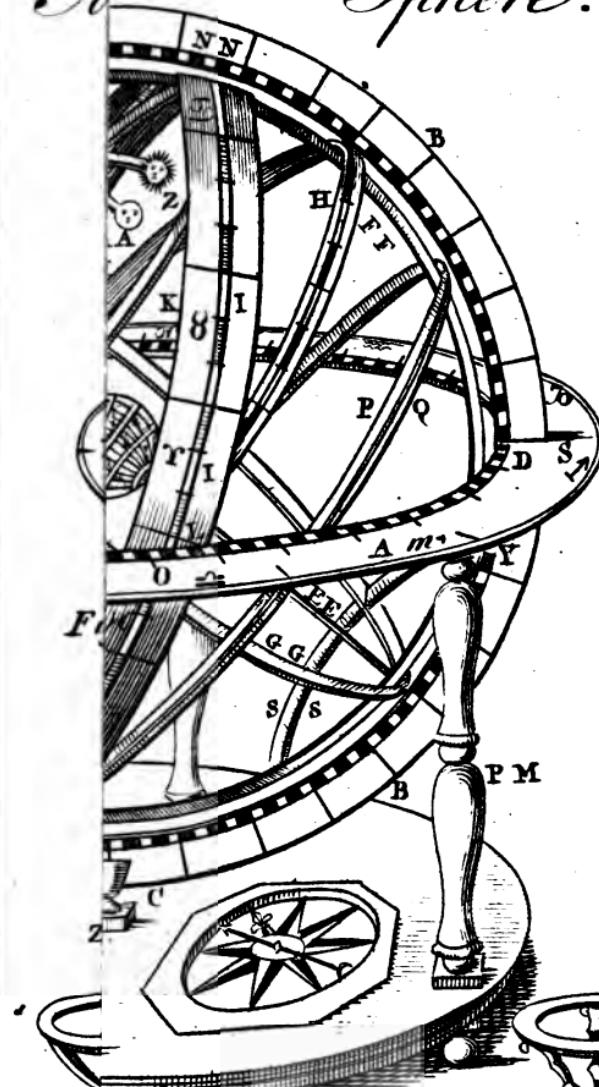


Fig. 1



Fig. 3

the Order of our Days in all Countries, let us inform ourselves of the full Value of what they left us: And we may begin with the Structure and Use of the Armillary Sphere.

What they call the Armillary Sphere, The Armillary Sphere. is the Collection of several Circles, so disposed among themselves, as to imitate the several Lines, that were imagined in the Heaven to represent the Path or Passage of the Stars, which revolve therein, and the exact Bounds which terminate their Courses. Whatever we perceive in the Heaven, with regard to us, is seen in a concave Sphere. A convex Globe, which is seen only without, not being naturally fit to represent a Concavity to us, they bethought themselves of constructing a hollow Sphere, in the Inside of which all the Points which we are concerned to know, might be seen, by making it consist of these Points only tacked together, and by suppressing the rest.

Each Circle, either great or small, is divided into 360 Parts, called Degrees. Each Degree into 60 Seconds; each Second into 60 Thirds; and thus you may proceed with this Subdivision, as long as you think it fit or possible. The Division of the Circle into 360 Degrees, has been preferred to many others, on account of the Advantage it has of yielding many Subdivisions expressed by even Numbers, easy to be disjoined or collected: 360 may be divided into two Halfs, each 180° ; or into four Quarters, each 90° . The Quarter may be divided, as Need requires, either into three Times 30, or into nine Times 10, or into six Times 15, or into eighteen Times 5. Degrees are marked with ($^{\circ}$), Minutes with a little Stroke ('), Seconds with two (''), Thirds with three ('''), Fourths with four (''''), and so on.

The Axis of a Circle is a Line which is conceived to pass through the Centre, The Axis. and whose two Ends, called the Poles, are equally distant from all the Points that The Poles. bound the Circle.

The Horizon, which incompasseth the The Horizon. whole Sphere, is a Circle placed parallel, with regard to the Surface of our Abode, on four small

Columns *, fastened on a common Foot, or better still, on four little Consoles †, which meet below, to make the whole Machine conveniently revolve on a fixed Foot, by means of an Iron Pin.

The Horizon may much easier be supported on four Branches, or on two Semicircles of Paste-board crossing each other, and fastened by a simple Foot ‡. If we imagine a Line perpendicularly falling on the Middle of the Horizon, and having both its Ends equally distant from it, it will be the Axis of the Horizon. The two Points, which terminate the Axis, are called Zenith and Nadir. The Zenith is above Z E, and Nadir below N A.

The Meridian, which may be made of Paste-board or of Wood, but more usefully of Brass, is a large Circle vertically inserted into the Horizon, into which it enters one Half: It must be fastened there, without being able to deviate either to the Right or Left; but it revolves freely therein downwards from above, and from below upwards, by sliding in a Groove C, which fixes it upon the Foot, and in two Notches D, made in the Circle of the Horizon.

The Axis of the World E F is an Iron Rod, which crosses the small terrestrial Globe placed in the Middle of the Sphere, and reaches from one Side of the Meridian to the other. The upper End of this Axis is called the Arctic Pole A P. The under is called the Antarctic or Southern Pole S P. We must not mistake the Axis of the World, extended from Side to Side of the Meridian, for the Axis of the Meridian itself. If we had a Mind to give the Meridian an Axis, by keeping it equally distant from all the Extremities of that Circle, the two Ends of it would be in the Horizon, and that Line, together with the Meridian,

The Cardinal Points. would cut the Horizon into four Quarters. The two Points, through which the Meridian passes in the Horizon, are called North and South: North, on the Side towards which the Arctic or Northern Pole N, is inclined: South, on the Side under which the Antarctic or Southern Pole S, is found. The two other Points, at which the imaginary Axis

Axis given to the Meridian cuts the Horizon, are the East E, and the West W. These four Points are called Cardinal *, because all depends and moves thereon in the Operations.

They besides make two other Circles The Coluri.
Fig. 4. *κολυρούς*
καστ. cross, and revolve on the Axis of the World. These are placed the same Way as the Meridian, and are called the two Colures F F, G G; which Name signifies *cut* or *multi-Lated*: And very likely they obtained it on Account of the Notches which are made in these two Circles, that they may support the others which are to be cross-wise fastened to them.

The *Æquator*, or equinoctial Circle H, The *Æquator.* is placed at equal Distances from the two Poles of the World, and divides the Globe into two Hemispheres, the one called Septentrional or Northern, the other Meridional or Southern.

The Ecliptic I, is a Circle or Line The Ecliptic. which obliquely cuts the *Æquator*, and which deviates from it twenty-three Degrees and a Half on each Side.

This Line is exactly in the Middle of a circular Band, 16 or 18 Degrees broad, and called the Zodiac K. The Zodiac is divided into twelve Portions, every one of which contains 30 Degrees. It incom-passes the Space of the twelve celestial Signs, under which the Sun is successively placed in the Course of a Year. They made the Band of the Zodiac 16 or 18 Degrees broad, that it might inclose all the Space of the Heaven to which the Moon and Planets deviate from the Ecliptic. The Sun never leaves that Line: The Moon deviates from it to the Distance of five Degrees, and some Planets seven or eight Degrees.

The two Points, in which the Ecliptic cuts the *Æquator*, are called Equinoxes, The two Equinoctial Points. or Equality of the Day or Night, *viz.* the Equinox of the Spring at the first Degree of *Aries* L, and the Equinox of Autumn at the first Degree of *Libra* M.

The Points of The two Points, where the Ecliptic deviates from the $\text{\textae}quator$, are the Solstices, or the Bounds of the Course of the Sun, *wiz.* the Summer Solstice, at the first Degree of *Cancer* N N, and the Winter Solstice, at the first Degree of *Capricorn* O O.

The Tropics. The two Tropics P Q are parallel to the $\text{\textae}quator$, from which all their Points are distant 23 Degrees and a Half. When these Machines are made in large, the true Distance is 23 Degrees and 29 Minutes. Nothing is to be overlooked, when the Largeness of the Instrument admits of that Exactness.

That of these two Circles, which is towards the North, is called the Tropic of *Cancer*, and the other, the Tropic of *Capricorn*; of which it touches the first Degree.

The Polar Cir. Let us give the Ecliptic an Axis: This Axis will deviate from the Poles of the

World, or from those of the $\text{\textae}quator$, which are the same; by so much as the Ecliptic itself deviates from the $\text{\textae}quator$ it crosses; it recedes 23 Degrees and a Half from it; consequently the Axis of the Ecliptic will deviate 23 Degrees and a Half from the two Poles; and if we turn the Sphere about, the Ecliptic will always have its Axis at the Distances of 23 Degrees and a Half from the two Poles of the World, and there delineate two small Circles, one called the Arctic Polar Circle R, the other the Antarctic Polar Circle S S.

Finally, round the Arctic Pole, and on The Horary the Meridian without, the little Circle, Circle. called the Horary Circle T, divided into 24 equal Parts, is fixed. On the Extremity of the Axis is a Hand V, whose End reaches to the Circle; so that if you cause the Sphere to make a whole Revolution, the Hand, which turns together with the Axis, will successively pass over the four and twenty Divisions of the Horary Circle.

To these circular Lines they add two Quadrants, the Situation of which must be carefully observed. If you introduce in Imagination an Axis in the Plain, and through the Centre of the Ecliptic, that Plain deviating from the $\text{\textae}quator$ 23 Degrees and a Half on each Side, and resting on the Colure of the Solstices in N N, and on O O, the Line,

Line, which you make perpendicularly pass through that Plain, will reach the opposite Sides of the same Colure, and exactly at the Distance of 23 Degrees and a Half from the Pole of the *Æquator*, in X and Y. Instead of an imaginary Hand, or an Index of Metal, which would incumber the Sphere, fasten in the Point X a Piece of Metal, or a Pivot, that may represent the Remainder of the whole Axis of the Ecliptic, which had been taken away. Make two Quadrants to revolve on that Point, the one larger, the other smaller, with a little Interval between the two, and having both their Extremities under the Circle of the Ecliptic. If you put a little Sun at the End of the large Quadrant Z, and the Figure of the Moon at the Extremity of the smaller Quadrant A A ; by pushing with your Finger the two Quadrants, either together or separately, and contrary Ways, you of Necessity must see the little Figures of the Sun and Moon moving under some of the Points of the Ecliptic ; since these Quadrants, which are both of 90 Degrees, revolve round the Axis X, distant 90 Degrees on every Side, with regard to the Ecliptic I. For this Reason, they make up the Quadrant of the Moon of two broken Pieces, to make the Moon decline *ad libitum*, and express pretty nearly its Deviations from the Ecliptic. I forgot to tell you, that in order to set these two Quadrants freely in Motion, the Axis of the World E E must be cut in B B, to leave them a Passage. The rest of the Axis E, being Iron, will always preserve its Place without any Disorder.

They then reckon in the Sphere six great Circles, five little ones, two Quadrants, and twelve principal Points. The six great Circles, whose Plains pass through the Centre of the terrestrial Globe placed in the Middle of the whole Machine, and which cut the Earth into two equal Parts, are the Horizon A, the Meridian B, the two Colures F F, G G, the *Æquator* H, and the Ecliptic I. The five little Circles, which cut the Sphere into unequal Portions, are the two Tropics P Q, with the Polar Circles B B, S S, and the Horary Circle T, which is not so much in, as annexed to the Sphere. The Points of more important Use are the Zenith Z E, and the Nadir N A, the Arctic Pole A P, and the Antarctic S P, the North N, and the South S ; in the Intersections of the Meridian with the

Horizon, the East E, and the West W, in the same Circle; the Equinoctial Points L, M, and the Points of the Solstices N N, O O. Then let us join the Axis E E, which supports the Whole, the End of the Axis of the Ecliptic, with the two Quadrants, the one for the Sun Z, the other for the Moon A A, and we shall have all the Pieces together. Let us now come to the principal Uses made of them: In the mean Time you will learn the Reasons of the Names given them.

First let us observe what most concerns us in Nature. The Sun, which lights us, seems every Day to advance from East to West. Besides, we see it daily changing, in a regular Manner, the Points of its Rising and Setting, and yearly passing through the same Points again. It then has two Motions, the one called diurnal, the other called annual. The Quadrant Y Z will now illustrate both these Motions, and though they be contrary to each other, nothing is more easy to be conceived, than the meeting of both in one and the same Star. Bring the Sun Z to the Vernal Equinox L, and cause the Sphere to make an entire Revolution from East to West: The Sun placed in the Heavens will be carried away with the Sphere. It will ascend and descend: You will see it move from East to West, and ready to begin the same Revolution again. It never leaves the Point of the Ecliptic where it is, and yet you see it describe in Space a Line perfectly like the Äquator; so long as the Revolution of the Sphere continues, you see it under the Äquator. If after this Revolution you give the little Sun a gentle Thrust, and cause it to advance towards the East, you may then bring it under the Meridian, and see by how much it will be distant from the Äquator, of two, or 12, or 23 Degrees, as you please. If the little Sun is two Degrees distant from the Äquator, and you cause the Sphere to revolve from East to West, it will pass through all the Points of Space which are two Degrees distant from the Äquator. If it happens to be 23 Degrees distant from it, it will pass through all the Points of Space 23 Degrees distant from the Äquator. If you join all these Points in Imagination, you will make of them a diurnal Circle parallel to the Äquator, and which will express the Revolution of the true Sun placed at two, or ten, or twelve,

or

or 23 Degrees from the celestial $\text{\textae}quator$. Your imaginary Sun has two Motions; the one by which you make it go from one Degree to another, and from West to East under the Ecliptic, whence it never deviates; the other, by which the whole Sphere, of which it is a Part, carries it away in a quite contrary Manner from East to West. We may conceive, that it is the same with regard to the true Sun: Let us suppose the Heavens to revolve from East to West; the Sun, which makes a Part of them, is carried away from East to West with the whole Mass of the Heavens: And this is the daily Motion. Let us likewise suppose, that the Sun has a peculiar Motion, by which it advances by very slow Steps in the Ecliptic, going from West to East: This shall be the annual Motion. We then shall see it appear sometimes under the $\text{\textae}quator$, sometimes it shall reach the Tropic; then be found between the two: After that it shall repass the $\text{\textae}quator$, and by continuing its proper Motion under the Ecliptic, by little and little reach the opposite Tropic, without ever advancing farther, because it never leaves the Ecliptic:

The Combination of these two opposite Motions may, as we already remarked in regard to the Moon, be explained by the Motion of a Fly placed on the Edge of the broad Wheel of a Crane wrought by Hands. While the Wheel descends the Fly may crawl upwards: The Wheel has one Motion, the Fly has another: But that of the Moon is not presently perceived. On the contrary, it appears to be carried away as well as the Wheel. However, if the Fly, always ascending in a contrary Direction to that of the Wheel, obliquely passes from one Edge to the other, though we see it constantly in the Air describing Lines parallel to either Edge; we also shall see it arrive, sometimes at the Middle of the large Wheel, (and this represents the Sun in the $\text{\textae}quator$): It shall afterwards arrive at one Edge or the other (and this represents the Sun in the Tropic). Therefore the daily Motion of the Sun from East to West is not, properly speaking, the Motion of the Sun, but of the Heaven to which it is fixed: The passing of the Sun over all the Degrees of the Ecliptic, going from West to East, according to the Antients, is the true Motion of that Star.

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The Sun being by this his peculiar Motion got to the Point of the Ecliptic, the most distant from the *Æquator*, as N N or O O, if that Point be carried away with the Heaven, it can be only on a Path every where distant 23 Degrees and a Half from the *Æquator*; and this was represented by the Circle of the Tropic, which the Sun shall seem to describe when arrived at that Point. They give that Circle the Name of Tropic and Solstice; the latter *, because it is the Bound of its Course, or of its Distance, with regard to the *Æquator*; the former, *Tropic*, or, *Reversion*; because the Sun, as it pursues its Course through the Ecliptic, leaves that parallel Circle to draw near the *Æquator* again.

You may give the Moon A A the same Motions you caused the Sun to make. If you bring the Moon between the Sun and the Earth, you will have an *Eclipse* of the Sun: If you put the Earth in the Middle, it is an *Eclipse* † of the Moon.

As we study the Heaven only to know the Relations it has to the Earth, let us now transfer all the Circles just mentioned, to a terrestrial Globe of a reasonable Size, and where every Thing may be better perceived than on the little Globe found in the Centre of common Spheres, which are generally rough and imperfect. You see, Sir, that the Poles of that Globe will correspond with the celestial Poles, and make a Part of the Axis of the World: That by delineating on that Globe a Line equally distant from both Poles, you will have an *Æquator* in all Points corresponding to those of the celestial *Æquator*; that by delineating on it the other Lines with the same Proportion, and in the same Degrees, you will have a terrestrial Ecliptic, two Tropics, two Polar Circles, and in short, all the Points correspondent with those of the Heaven. All these Lines, transferred from the celestial Sphere on a Globe, divide it into as many Bands or broad The Zones. circular Portions, which are called Zones.

The Space round the Globe contained between the Tropics, is called the *Torrid* or *burning Zone*; because

* *Solis statio*, the Bound of the Sun. *Τρόπαι ήλιος*, the Return of the Sun. *Hom. Odyss.*

† From *inæstis*, *deliquium*, Faintness or Decay, comes the Word *Eclipse*.

because the Sun never leaves it. The two Spaces between the Tropics and the two Polar Circles are the Temperate Zones, one Northern, the other Southern. The Spaces inclosed within the Polar Circles are the Frigid Zones.

Now place your Globe within a Meridian that supports its Axis, and put the whole in an unmoveable Horizon, wherein the Meridian may slide, and the Globe freely revolve. You may then at your Choice, and as Occasion requires, operate either upon the Sphere or on the terrestrial Globe. What we shall say of these Lines, and of the Uses made of them, is equally to be understood of either of these Instruments, which we shall handle alternately.

Of all the Circles the Horizon alone has a sensible Existence in Nature. The others are almost made up of a Train of Points, through which the Sun or some other Star shall have passed. These Points may be a real Passage: But they are not seen, and can only be conceived; whereas the Horizon is composed of all the Points that bound our Sight *, or which determine that Half of the Heaven, or upper Hemisphere, which we see, and mark out the Separation of it from the inferior Hemisphere, which we do not see. These two Halves of the Heaven are equal, or nearly so: For the Earth being as a single Point, in Comparison of the starry Heaven, the Obliquities, and even the whole Body of the Earth, are here of no sort of Consideration. They hinder not the Earth from being but a single Point, in the Line or Planet that divides the Heaven into two Parts. They hinder not the Eye, placed on that Point, from seeing the upper Half as large, or almost as large as the Inferior: And in Reality we see the Stars diametrically opposite, as the *Hyades*, which are in the Forehead of *Taurus* on one Side, and those of the *Scorpion* on the other, appear on the two opposite Borders of the Horizon at the same Time.

The Horizon of every Place being determined by two vertical Points, the one Superior, called Zenith Z E, the other Inferior, called Nadir N A, both distant 90 Degrees from the Borders of that Horizon; if you leave that Place, and change your vertical Points; you of

L 6

The Immobility of the Horizon in Spheres.

Course

* From ὅριον. Mountains that bound our Sight, comes ὅρισμα, to bound, determine.

Course change also your Horizon; and if you advance under a new Zenith, five, ten, or twenty Degrees distant from the first, the new Horizon likewise will discover five, ten, or twenty new Degrees of the Heaven before, and hide as many behind us, because the Horizon is always, and on all Parts, 90 Degrees distant from the Zenith. We therefore ought to have a moveable Horizon, that might be turned *ad libitum*, in order to represent the Horizon of every Point of the Earth: But it is one and the same Thing, to place the Horizon at 90 Degrees Distance from whatever Point you may be pleased to chuse in the Globe, or to turn the Globe itself, and bring the proposed Point to 90 Degrees from the Horizon. For this Reason they have made the Horizon firm and unmoveable in Spheres; because it, as it were, multiplies itself, and by the Mobility of the Globe becomes the Horizon of all the Points of the same. But we cannot find the Horizon of any Place proposed, without knowing the Use of the Meridian.

The Meridian is a great Circle that passes through the Poles of the Sphere, through the vertical Points of a proposed Place, and through some Point of the *Æquator*. If we go from North to South on one and the same Line, conceived and delineated after this Manner, we change not our Meridian: But if we go from East to West, we incessantly change our Meridian, and we may reckon as many Meridians as there are Points in the *Æquator*. However, as a single Horizon is sufficient in the Sphere for all the Points in the World, a single Meridian likewise may become the Meridian of any Place; since by turning the Globe you may bring what Place you please under the common Meridian, which will supply the Place of all others.

As the Horizon cuts the World into two Hemispheres, so the Meridian cuts the Horizon into two equal Parts; the one Eastern, where we see the Stars ascend, the other Western, where we see them go down. The Duration of the Day is that Time, in which the Sun appears in our Hemisphere. The Meridian which divides that Hemisphere into two equal Parts, does of Course also cut the Duration of the Day into two equal Portions: It is Mid-day when the Sun touches that Circle; and for this Reason it is called the Meridian, or the Divider of the Day. The

The chief Uses, to which the Sphere and Globe are applied, depend on the Knowledge of the Points marked on the Meridian and the Horizon.

The Points marked on the Meridian are, First, The 360 Degrees of the Circle, disposed in four Nineties, which are reckoned from the *Æquator* to the Poles. Secondly, The Climates, or successive Increases of the Days from the *Æquator* to the Poles.

The Points marked on the Horizon are of three Kinds: First, on the inner Border of the Horizon were brought down the 360 Degrees of the Ecliptic, together with the twelve celestial Signs, which were placed by Thirties, placing the first Degree of *Aries* and the first of *Libra*, in the two Points where the Axis of the Meridian, if it had one, would certainly have been. Secondly, The next Circle in the Horizon contains the twelve Months and the 365 Days of the Year, over-against those Degrees of the Ecliptic under which the Sun is in every one of these Days. Thirdly, The last Round of the Horizon contains the Names of the Winds, according to their several Quarters.

This Order of the Horizon is the same in the Armillary Sphere, in the terrestrial Globe, and that which represents the Heaven at large, with the Animals after which the Stars are named. But making use of a celestial Globe, you, perhaps, will be surprized not to find the Calendar of the Horizon agreeing with the Marks or Figures of Animals which are delineated in the Ecliptic on the Globe itself. In the Horizon, the 10th of *March* corresponds with the first Degree of *Aries*, and that first Degree touches the Equinox of the Spring, or the Intersection of the Ecliptic on the first Degree of the *Æquator* on the East Side. You likewise will find there the 11th of *June* marked over-against the first Degree of *Cancer*, where is the Point of the Ecliptic the most deviating from the *Æquator*; and that is the Summer Solstice. You then will see there the 12th of *September* placed over-against the first Degree of *Libra*, and at the other Intersection of the Ecliptic, on the 180th Degree of the *Æquator*, which is the Autumnal Equinox. Lastly, you see the 11th of

The several Uses of the Globe.

December.

December placed over against the first Degree of *Capricorn*, where the Ecliptic declines most from the *Æquator* toward the South Pole: And that is the Winter Solstice. If from the Edge of this Horizon you carry your Eye to the terrestrial Globe, you will there indeed find the compendious Mark or Character of *Aries*, near the Intersection on the first Degree of the *Æquator*; but the Stars themselves of *Aries*, and the Figure of the Animal, which comprehends them within its Extent, are thirty Degrees farther towards the East. All the compendious Marks of the other Signs are placed on the rest of the Ecliptic as they are marked on the Horizon. But the Signs themselves, or the Animals with their Stars, begin 30 Degrees farther towards the East. Whence then can this prodigious Difference between the Calendar of the Horizon, and the Order marked on the Globe, proceed?

This Difference is what they call the Precession of the Equinoxes. The first Astronomers, who constructed the Sphere, took Care to place the first Degrees of the Signs just named, at the Points of the Equinoxes and Solstices. They had reckoned thus of a long Time, and were persuaded, that the Stars seen in those Points never left them. However, they observed by Degrees, that the first Star of *Aries* deviated by the Space of a Degree from the Point of the Equinox towards the East, and that within the Space of seventy Years; and now all the Signs are at last advanced 30 Degrees towards the East, and distant from those Points to which they gave their Names. But these Points still keep the Names of the Signs, which are no longer there: Though the Sun, on the 10th of *March*, be under the first Degree of *Pisces*, they still say, as formerly, that it enters *Aries* on that Day. It is the same with the rest respectively: Which, by the bye, is a new Matter of Shame and Confusion to Astrologers. They give to *Libra* benign and favourable Influences, to the *Scorpion* Malignity, and the other Signs Effects agreeable to the Nature of the Animals or Objects of which these Signs bear the Names. More especially they pretend, that the whole Activity of the Influence appears, the Moment when such or such a Sign begins to ascend the Horizon: But their Pretences are most frivolous; since, when they say a Man is born under the dangerous Aspect



The aspects of the Heaven.



Aspect of *Scorpio*, it was really the *Sign Libra* which came above the Horizon, the Moment of that Man's Birth, and it is the *Sign Gemini* which ascends, when they talk of *Cancer*, and so of the rest.

As the whole Sphere, or Globe, may successively have all their Points brought under the Meridian, and the Meridian may lower or heighten the Axis of the World, by sliding within the Notches of the Horizon; it is an easy Matter for us to determine the Aspects of the Heaven, with regard to all the People of the Earth; to measure the Distances of Places; to know the Duration of Days and Nights for such and such Places; the Moment of the Rising and Setting of the Sun, the Hour of its being in such or such Place, when it is Mid-day in another; in short, to answer, by the Help of a Sphere or a Globe, all the Questions relating to the Situation of Places, either with regard to each other, or with regard to the Sun and the whole Heaven.

If we have a Mind to know the several Horizons of Nations, and the Manner in which they see the Sun, we must begin by looking in the Aspect of the Heaven, with regard to those People who are under the *Æquator*. And that we may judge of all by a single one, let us for Instance take the City of *Quito*, situated on the northern Limits of *Peru*, at a Distance pretty nearly equal from both Poles of the Earth.

* Bring *Quito* under the Meridian: The Degree of the Meridian, which shall correspond to it, will be the Zenith of *Quito*. Raise that Zenith above the Horizon, till you may reckon 90 Degrees from that Point to the Horizon: Then you will perceive the two Poles of the World brought into the Horizon. *Quito* has then its Zenith in a Point of the celestial *Æquator*, and 90 Degrees Distance from each Pole of the World. In this Situation, the *Æquator*, and all the Circles parallel to it, will cut the Horizon directly, and without inclining on one Side more than on another. The Horizon reciprocally cuts the *Æqua-*

* You may, in order to make the Meridian move without any Hindrance, take off the two Screws that fix the Horary Circle on the Meridian.

Æquator, and all the Circles parallel to it, into equal Parts. This is what they call the Rectangular Horizon, or a Right Sphere.

The Results of this Situation are these:

We have Day so long as the Sun remains above the Horizon: Now all the Circles, which the Sun describes from one Tropic to the other on the Horizon of *Quito*, are cut into two equal Portions by that Horizon, since they fall thereon directly. The Days are then equal to the Nights, all the Year; that is, the Day is twelve Hours, and the Night the same.

As the Sun there descends directly under the Horizon, it goes much quicker from it, than if it sunk obliquely under it. Therefore the Twilight must be shorter at *Quito*, than in those Places where the Sun crosses the Horizon obliquely.

The Sun is three Months in its Passage through the Ecliptic, from the first Degree of the Æquator to the Tropic of *Cancer*, and three Months more in its Return to the Æquator, or the first Degree of *Libra*. When it is come to that Point of the Ecliptic which cuts the Æquator, it is carried by the Motion of the Heavens, on a Circle which represents the celestial Æquator, and which passes vertically over all the Points of the terrestrial Æquator. It then at that Day passes through the Zenith of *Quito*, and will again pass over it six Months after. The Inhabitants of *Quito*, and all such as live under the Equinoctial Line, will then twice in a Year see the Sun perpendicularly passing over their Heads.

Let us now leave the Equinoctial Line, and make choice of some other well known Place in the Torrid Zone: For Instance, *Mexico*, the Capital of *New Spain*. I bring this under the Meridian, and find that it corresponds to the 20th Degree marked on that Circle. It has then a Zenith 20 Degrees distant from the foregoing, and from the celestial Æquator in which the Zenith of *Quito* is. When we were at *Quito*, our Horizon touched both Poles. All the Stars, revolving round the Poles with the Heaven, rose and set in that Horizon. The Horizon of *Quito* cut in Half all the Circles described by each individual Star. The Points of the Poles alone remained invariable, and in

the Horizon. But now we are brought to *Mexico*, it is no longer thus. We have removed twenty Degrees from the *Æquator* towards the Arctic Pole. Our Horizon must no longer terminate in the Arctic Pole, but be twenty Degrees lower down, and rise behind us twenty Degrees above the Antarctic Pole, which will then be hidden. We therefore determine the Horizon of *Mexico*, and of any other Place, by elevating the Pole above the Horizon, as many Degrees as the Place intended is distant from the *Æquator*. For, bringing the Horizon under the Pole, or elevating the Pole above the Horizon, is one and the same Thing; and we only elevate the Pole, because the Horizon is fixed both in Globes and Spheres.

In this new Disposition of the Sphere which is called oblique, I find every Thing different. The *Æquator* alone is cut into two equal Parts by the Horizon. The Tropic of *Cancer*, which is nearer the elevated Pole, is more above than it is under the Horizon; and the Tropic of *Capricorn* on the contrary, which is nearer the depressed Pole, is now cut by the Horizon into two unequal Parts, the smaller of which is in the visible Hemisphere, and the larger in the inferior. All the Circles parallel to the *Æquator*, which the Sun describes from Day to Day, by the Motion of the Heaven that carries it with itself, will be proportionably cut with the same Inequality. The Inequality will be less, in Proportion as the diurnal Parallels shall be less remote from the *Æquator*. The Portion of the Circle the Sun shall describe above the Horizon of *Mexico*, will always be smaller and smaller, as it draws towards the Tropic of *Capricorn*. This diurnal Arch will constantly increase, in its Progress towards the Tropic of *Cancer*. Hence the Increase of the Length of the Days, and the Diminution of the Nights, towards the Summer Solstice. Hence the Decrease of Days and the Length of Nights, as the Sun approaches to the Winter Solstice: Hence in short, the Equality of the Day and the Night, when the Sun describes the Arch of the *Æquator*; since the Horizon of *Mexico*, cutting that Circle into two equal Parts, renders the diurnal Arch equal to that which the Sun passes through in the lower Hemisphere.

Next

Next we shall observe, that the Sun being come in the Ecliptic to 20 Degrees of Declination from the Äquator, that Day describes, by the Motion of the Heavens, a Circle parallel to the Äquator, and passing through all the Points which are twenty Degrees distant from the Äquator. It will then pass through the Zenith of *Mexico*. Continuing its Progress in the Ecliptic, it will decline from *Mexico* only three Degrees and a Half towards the North, before it arrives at the Solstice; since the most declining Point of the Ecliptic is but 23 Degrees and a Half distant from the Äquator. Continuing its Course in the Ecliptic, it will necessarily repass the Declination of 22° , then gradually proceed to that of 21 , and at last, that of 20 Degrees. It will therefore on that Day describe, anew, a Parallel, which will pass again through the Zenith of *Mexico*. It will then, twice in a Year at Noon, pass directly over the Heads of the People of *Mexico*; and so generally over that of all the Inhabitants of the Torrid Zone. For, if I bring for Instance the Town of *La Plata* * on the Horizon, and the Mines of *Potosi*, which are on the Borders of *Peru* in *South America*, nearly equally distant from the Äquator, by raising the Antarctic Pole 18 or 20 Degrees above the Horizon, I shall find the very same Effect, and with a Disposition intirely alike. Only the Days, which were the shortest at *Mexico*, will be the longest at *La Plata*, which lies on the other Side of the Äquator.

Let us now return to *Mexico*, and see what are the Days of the Year when the Sun is to pass through the Zenith of that or any City. The Operation for one will serve as a Rule for all the rest: We need only see what are the Points of the Ecliptic which pass under the twentieth Degree of the Meridian, where I am informed that the Zenith of *Mexico* is. By turning round the Globe, I see two Points of the Ecliptic passing under the twentieth Degree of the Meridian. First, I see the 26th Degree of *Taurus*, and continuing the Revolution, the third Degree

of

* *La Plata*, in *Spanifh*, *The Silver*. The Silver City, thus called on Account of the Mines of that Metal in its Neighbourhood. They have since abandoned them, to beslow the more Pains. on the Silver Mine of *Potosi*, eighteen Leagues from *La Plata*.

of *Leo* passing under it. I look out, in the Horizon, to know what Days of the Year correspond with both these Points. I find that the 18th of *May* answers to the 26th Degree of *Taurus*, and the 26th of *July* to the third Degree of *Leo*. I then thereby know, that the Sun passes perpendicularly over *Mexico* on the 18th of *May*, and the 26th of *July*; and as it recedes but very little from the Zenith of *Mexico*, before it comes to the Solstice, which declines but three Degrees and a Half from it Northward; the Sun, for three Months together, passes at Noon almost directly over that City, and the Heads of all the People near the Tropics. The Summer ought consequently to be much more insufferable there, than in the Middle of the Torrid Zone, and under the Equinoctial Line, from which the Sun deviates much faster. But we have already observed * from the general Consent of Travellers, that by a special Providence of the Creator, the *Etesian* Winds bring towards the Tropics, when the Sun draws near them, such a vast Quantity of Fogs and Rains, that the Summer, which would otherwise burn them, in Reality becomes their Winter, or the coldest Season they have.

As the Pole is twenty Degrees above the Horizon of *Mexico*, the Stars, which are less than twenty Degrees off, will never set with regard to that City; since the Circles they describe never fall under the Horizon, and are never intersected by it. Therefore the *Ursa Minor* will be seen every Night at *Mexico*. But the *Ursa Major*, which is a great deal more than 20 Degrees distant from the Pole, shall rise and set there. Whereas it is always seen in our Climate, because as we are 49 Degrees distant from the *Æquator* here at *Paris*, our Pole is so much elevated. Now the Limits of the Circle, which the seven Stars of the Chariot or *Charles-Wain* describe round the Pole, recede only forty Degrees from the Pole: They then do not go down under the Horizon: Nor do they set with regard to us.

Let us now bring under the Meridian some Country that stands in the Middle of the Temperate Zone, as *Hungary*, *Austria*, *France*, *Acadia*, or the *French Colony*, which now inhabits both Sides of the River *St. Lawrence*. We

for

for Instance shall find *Quebec*, which is the capital Town of *New France*, 47 Degrees distant from the *Æquator*. The Pole, elevated 47 Degrees above the Horizon, shall give us the Aspect of the Heaven, answerable to the Situation of the capital Town of *Canada*. In this Situation we shall see one Half of the *Æquator* above, and one Half under the Horizon; but at the same Time all the diurnal Parallels cut with a greater Inequality than they were at the Horizon of *Mexico*. The Tropic of *Cancer*, which rises above the Horizon, together with the Pole adjacent, is almost Two-thirds elevated above the Horizon. The Day must then, in the Time of the Solstice, be there almost Two-thirds of four and twenty Hours long. On the contrary, the Horizon cuts the Line of the Tropic of *Capricorn* in such a Manner there, that it is almost Two-thirds sunk under the lower Hemisphere. Days must then be there but eight Hours or somewhat more, towards the 22d Day of *December*. We shall soon see, how the little *Horary Circle*, with its moving Hand, shews us the Duration of Days on every Horizon, without Trouble or Calculation.

Let us fix our last Station within the Space which extends from the *Æquator* to the Pole, and stop at *Torneo*, a large Town which we find at the Bottom of the Gulph of *Bothnia*, terminating the *Baltic Sea*, at the Entrance of *Lapland*, and almost under the *Arctic Polar Circle*. *Torneo*, when brought under the Meridian, there finds its Zenith at the Beginning of the 67th Degree of Distance from the *Æquator*. The Pole, elevated as many Degrees above the Horizon, carries with it the Tropic of *Cancer*, so far as to keep it wholly above the Horizon, or touching the Horizon with its lower Extremity. As the Pole is there elevated 67 Degrees, there can remain but 23 Degrees from that to the Zenith, for completing the Number 90 Degrees. There are from that Zenith to the *Æquator* the 67 Degrees which served me for a Rule, and from the *Æquator* to the other Tropic 23 Degrees, or a little more, which are in all the other 90 Degrees that reach on the opposite Side as far as the Horizon. The Horizon of *Torneo* does then touch on one Side the lower Border of the Tropic of *Cancer*, and the highest Point of the Tropic of *Cancer* on the other. Thus the whole Tropic of

of Cancer is above, and the whole Tropic of Capricorn beneath the Horizon. In the Middle of the Summer, when the Sun describes the Tropic of Cancer, the Day will there be four and twenty Hours long. The Sun, by lightly touching upon the Horizon, perhaps will meet there with some Eminence, and possibly hide itself behind it: But it will rise and be seen again an Instant after. On the contrary, the Sun being, on the 22d of December, come to the Tropic of Capricorn, shall describe a Circle, of which there will not be the least Portion above the Horizon. It will therefore not be seen there for four and twenty Hours together: At most it will rise above the Horizon with its upper Extremity only, and by a few wandering Rays shew the Day-break; but it will immediately sink back again into the inferior Hemisphere; unless the Refractions, occasioned by the Atmosphere, make it visible for a few Minutes above the Horizon, while it is really under it. I need not repeat to you, that in all Situations of the inclined Sphere, the \textcircumflex Equator has always one Part above the Horizon, equal to that which is under, whence comes the Universality of twelve Hours Day and twelve Hours Night all over the Earth, when the Sun is describing the Equinoctal Line. The Reason of the Division of the \textcircumflex Equator into two equal Halves for all Horizons, and of the Division of the Parallel Circles into two unequal Portions, is grounded on the Horizon and the \textcircumflex Equator's being two great Circles having the same Centre, *viz.* that of the Earth; whereas the diurnal Parallels, which the Sun describes from the \textcircumflex Equator to both Tropics, recede more and more from that Centre towards the Poles: Whence it follows, that the nearer these Parallels draw toward the elevated Pole, the more they themselves rise above the Horizon, and there prolong the Day. On the contrary, the more they sink under the Horizon towards the Pole depressed, the more they lessen the Length of the Day above the same Horizon, while they lengthen it in the inferior Hemisphere.

It now remains, that we should place ourselves under the Pole, and examine the Aspect of the Sun, with regard to such as have the Pole itself for their Zenith. If that Part of the World is habitable, they must needs have the Horizon in the \textcircumflex Equator; for the Pole and the Zenith being

being the same Thing, they both find the \AA quator and the Horizon at 90 Degrees Distance on every Side. They

The Parallel are united or become parallel to each Sphere, or the other: For which Reason, this Disposition Parallel Hori- of the World is called the Parallel Sphere.
zon. You see the Consequences of it. The

Sun is six Months together on this Side the \AA quator to-
wards the Arctic Pole, and six Months on the other. If
the \AA quator is the Horizon of the People which dwell
under the Pole, they would see the Sun going six Months
together round them, rising by Degrees, during the first
three Months, to the Height of 23 Degrees and a Half,
and during the other three Months sinking by Circles
disposed in the Form of spiral Lines; till-about * the
26th or 27th of September, describing a Parallel Circle,
which then begins to recede from the \AA quator, it quits
their Horizon also.

Are then these People for six Months together buried
in profound Darkness? Far from it. They enjoy a
perpetual Aurora, till the Sun is fallen 18 Degrees, or
perhaps more, under the \AA quator, or the Horizon,
which are here the same Thing. The Sun is two Months
before he gets thither, and in two Months more he
comes thither again, and begins a new Twilight, which
promises Day two Months before the Rising of the Sun.
Reckoning these Twilights for a Part of the Day, they
are inlightened ten Months together, and during the two
Months of their Night, the Moon going twice the same
Course which the Sun makes in a Year, they see it
above their Horizon two half Months of that Time:
Thus they pass no more than two Fortnights all in in-
tire Darkness. Nay, we may affirm, from a Multitude
of Accounts, that the Twilights being much greater
towards the Poles than in our Climates, they enjoy them
even before the Sun has reached the 18th Degree from
their Horizon: So that they have no Nights absolutely
dark, and even are, strictly speaking, of all Nations,
those that have the greatest Share of the Benefit of the
Light.

* I say the 26th, rather than the 23d, because they may see the Sun by Refraction many Days after it has passed the \AA quator, which is the Horizon of the Inhabitants of the Pole.

Light. We have at present no Certainty, that there are any People immediately under the Pole; so that we dare not affirm it: But the Thing is very possible; and we know, from the Accounts of the *Danes* and *Norwegians*, that the Situation of the *Greenlanders*, and of many *Tartars*, who are as fond of their Country as we of ours, is pretty near the same as that just described. A nicer Research would here be very needless. You see what Method is to be followed, to be certain when the Tropics are, or are not cut by the Horizontal Circle: On this Knowledge depends the Study of the Length of the Days in every Country.

Now, in a few Words, let us recapitulate what relates to the Horizon. The Zenith is either in the *Æquator*, or somewhere between the *Æquator* and the Pole, or, in short, the Pole itself is the Zenith. Those, who have their Zenith in the *Æquator*, see the Poles touching their Horizon, which, with regard to them, cuts the *Æquator*, the Tropics, and all the diurnal Parallels into two equal Parts; whence proceeds the perpetual Equality of Days in the right Sphere.

Those who have their Zenith between the *Æquator* and the Pole, see their Horizon as much below the Pole, as they themselves are distant from the *Æquator*. The *Æquator*, and all the diurnal Parallels, are inclined to that Horizon. The *Æquator* rises one Half above, and the other is hid under the Horizon. The Tropics and the Parallels are by it cut into unequal Portions: Even some Parallels near the elevated Pole are intirely disengaged from the Horizon, and the Parallels adjacent to the opposite Pole lie hid under it. Hence the Inequality of Days and Nights, and the perpetual Variety of those Inequalities in the extensive Length of the oblique Sphere.

Those, who have the Pole for their Zenith, have no other Horizon than the *Æquator*. Thus the Sun, which dwells six Months on this Side the *Æquator*, and six on the other, is up for six Months together, and lies concealed for a like Space of Time in the Parallel Sphere.

The Globe and the Sphere may still, without any Application or Study, soon inform us of the relative Distances of all the People, either from East to West, or from North to South. The Distance from East to West is called Longitude,

gitude, because the Antients had travelled that Way more, and knew a greater Extent of Country from East to West, than from North to South. The Distance from the North to the South is called Latitude or Breadth, compared with the other Extent, which the Antients thought was the greater; because in the Times when Sciences flourished in *Greece*, and still more in the Time of *Ptolemy*, long after the Commerce of *Andaloufia* * had ceased by the Way of the *Red Sea*, they were generally persuaded, that the Torrid and Frigid Zones were both uninhabitable. All the Poets are full of Passages relating to this false Opinion: Which, as you are sufficiently acquainted with, I need not quote to you.

Longitude, and In Imitation of *Ptolemy*, who has fixed its Uses. the first Meridian, or the Beginning of

the Longitude of Places, at the *Fortunate Islands*, which are our *Canaries*, because they were the most Western Lands known in his Time, the Northern Nations place the first Meridian in the Island of *Teneriffe*, that of the *Canaries* in which the *Pico of Tyde* stands. The *French* place it in that which is called the Island of *Ferro*. But there is now no Necessity for confining ourselves to that Manner of calculating Longitude; wherefore at present they generally reckon the Degrees of Longitude, from the famous Meridian-line that passes through *Paris*; because, having been drawn with the greatest Accuracy, it is the most known Term or Point to begin their Account at.

For Example, you have a Mind to know, how far *Pekin*, the Capital of *China*, is distant in Longitude from *Paris*. Bring *Paris* under the common Meridian, and then remove that Point towards the West, counting how many Degrees of the *Æquator* pass under the Meridian, till you see *Pekin* brought under the same. According to Mr. *De l'Isle's* great Globe, you will find 113 De-

The Definition of the Longitude. grees of the *Æquator* intercepted between the Meridian of *Paris* and that of *Pekin*. The Arch of the *Æquator* intercepted between the Meridian of *Paris*, and that of any other given Place, is therefore the Longitude of that Place.

In

* *Tarifis*.

In this Enumeration the Arctic Pole being always elevated, the Distance, which extends 180 Degrees to the Right, shews how much any given Place is more Eastward than another. The Distance, which extends 180 Degrees on the Left of *Paris*, shews how much any other given Place is more Westward than *Paris*. It might seem convenient therefore to call the 180 Degrees of the *Æquator*, which are on the Right of the Meridian of *Paris*, Eastern Longitude, and the other 180 Degrees, which are to the Left of the same Meridian, Western Longitude. But as it is an universal Custom to count one single Progression of Longitude up to 360 Degrees; we shall do the same whenever we have an Occasion to mention Longitude, according to Mr. *De l'Isle's* Globe. The first Advantage the Degrees of Longitude may be of, is, no doubt, to know the Distance from one City to another. But that Sort of Measure varies, and requires a very great Caution. The Degrees of Longitude under the *Æquator*, are 25 common Leagues: They are much less under the Tropics, and continually diminish toward the Pole; because all the Meridians, which pass through the 360 Degrees of the *Æquator*, unite in the Point of the Pole, and leave between each other Intervals always lessening as they draw nearer to the Pole. If we can apply the Knowledge of Longitudes to the reducing of these Degrees into Leagues, it can only be by Means of Tables, where the successive Diminution of these Degrees, as you advance towards the Pole, has been assigned. Here it will be sufficient to acquaint you, that the Degree of Longitude, which is 25 Leagues in Length under the *Æquator*, is no more than 22 Leagues, or thereabouts, under the 20th Degree of Distance from the *Æquator* towards the Pole; 21 Leagues at the 30th Degree of Distance from the *Æquator*; 18 Leagues at the 40th; 15 at the 50th; 12 at the 60th; 9 at the 70th; 5 at the 80th; and nothing at last at the 90th, that is under the Pole.

But the greatest Advantage we have from the Knowledge of those Degrees consists in reducing them into Time. Fifteen Degrees of the *Æquator* passing under the common Meridian are equal to 60 Minutes, or an Hour, and each Degree, of Course, is equal to four

Minutes; there being four Times 15 Minutes in 60. The 113 Degrees of Eastern Longitude, which are between *Paris* and *Pekin*, may then be reduced to seven Hours and 32 Minutes; by which Distance *Pekin* is more Eastward than *Paris*. So, when the Sun rises to us, it has already been up above seven Hours and a Half at *Pekin*; and when it is Noon to us, it is above Half an Hour after Seven in the Afternoon at *Pekin*; since they had Noon there above seven Hours and a Half before. On the contrary, *Quebec* being at 307 Degrees of Longitude from the first Meridian, or, if you will, having 73 Degrees of Western Longitude, with regard to the Meridian of *Paris*; the Sun will not rise at *Quebec*, till five Hours wanting eight Minutes after it has risen at *Paris*; and when it is Twelve o'Clock at *Paris*, it is hardly a Quarter after Seven in the Morning at *Quebec*.

The Definition and Uses of the Latitude.

The Latitude of a Place is its Distance from the \AA quator toward either of the Poles; and it being reckoned on the Meridian, we may define it to be, the Arch of the Meridian intercepted between the \AA quator and any given Place. For Instance, to find the Latitude of *Paris* or of *London*, you must alternately bring these two Places under the Meridian, and from the \AA quator to *Paris* you will reckon 49 Degrees, and to *London* 51 and a Half.

The Advantage of this Knowledge is, first, that we may reduce into common Leagues, of which there are 25 to each Degree, the Distances which are from the \AA quator to the Pole; not to enter here into the Dispute concerning the supposed Extension or Flattening of the Earth towards the Poles; which can occasion no great Difference, supposing the Earth to be not intirely round. Secondly, The Knowledge of the Latitude puts us in a Way to mount the Globe horizontally for any particular Place, that is, to determine the Horizon of it, in order to answer any Questions concerning the actual Time of Day, the Rising or Setting of the Sun in that Horizon on such a Day of the Year, and the Duration of the Days, Nights, and Crepuscles.

For Instance, suppose I want to know what o'Clock it is at *Torneo* in *Lapland*, when it is Twelve o'Clock at *Pe-*

is this 10th of *May* 1737. After having hastened the little horary Circle with its Hand on the Meridian, I bring *Torneo* under the Meridian; and finding it to have 67 Degrees of Latitude, I give the Pole an Elevation of a like Number of Degrees. I look out in the Calendar of the Horizon for the 10th of *May*, and find that it corresponds to the 19th Degree of *Leo*. I clap on the 19th Degree of *Leo* in the Ecliptic a very small Patch of white Paper; or if I don't care to daub any Thing, I bring under the Meridian the same Point of the Heaven, which I take great Care to remark, and under which the Sun is actually placed. If after having applied the Horary Hand on the Point of Mid-day, that is, on the uppermost of the two Figures marked XII, I cause the Globe to turn back towards the East; and the Moment when the 19th Degree of *Leo* touches the Horizon, the Hand will point at Half an Hour after Two for the Rising of the Sun above that Horizon. The same Point carried thence to the Meridian, and from the Meridian to the Western Border of the Horizon, will mark out the Path or diurnal Arch of the Sun over the Horizon of *Torneo*. The Horary Style will point at Half an Hour after Nine, the Moment the 19th Degree of *Taurus* sinks under the Horizon. Thus I am presently informed, that the Duration of the Day on the 10th of *May*, is 19 Hours, and that of the Night five Hours at *Torneo*; if we may call that Night, when the Sun, obliquely going down, sinks but three Degrees under the Horizon.

It is required, what the Aspect of the Heaven and the Duration of the Day will be for the same Place, on the 8th of *December*. I look for the 8th of *December* in the Calendar on the Horizon, where it corresponds to the 16th Degree of *Sagittary*. That Degree being brought under the Meridian, and the Hand placed at Noon, if you then turn the Globe so as to make the 16th Degree of *Sagittary* just appear above the Eastern Part of the Horizon, you will find the Hand pointing to Half an Hour after Eleven, the very Instant the Sun or that 16th Degree shall get above the Horizon: And when it shall pass under the other Edge of it Westward, you will find the Hand at Half an Hour after Twelve. Therefore the Day is but an

Hour, and the Night 23 Hours long on the 8th of December at Tornes.

To the Advantage of knowing the Elevation of the Pole, and of finding the Horizon of a Place, by the Knowledge of its Latitude, let us add that of knowing the Elevation of the *Æquator*, for the Horizon of the same Place.

When the Globe is horizontally mounted for *Paris*, you have 49 Degrees Distance between the Pole and the Horizon, just as you have them in Latitude between the *Æquator* and the Zenith. Now from the Zenith to the Horizon there are but 90 Degrees on every Side. If from these 90 you take the 49 of Latitude, there remain 41, which Number expresses the Height of the *Æquator* above the Horizon of *Paris*. The Height of the *Æquator* above the Horizon is then the Difference between the Number of the Degrees of the Elevation of the Pole, and 90 Degrees.

By this Means you know, that on the 21st of *March*, and the 23d of *September*, the Sun, which then describes the *Æquator*, at *Noon* is elevated 41 Degrees above the Horizon of *Paris*. Add the 23 Degrees and a Half of Declination, or of a greater Elevation towards the Arctic Pole, and you will have 64 Degrees and a Half for the Elevation of the Sun at *Noon*, on the 22d of *June*, that is, the Day of the Solstice. From the 41 Degrees, which is the mean Height, or that of the *Æquator*, take the like Sum of 23 Degrees and a Half, you will find 17 Degrees and a Half, for the Elevation of the Sun at *Noon*, on the Day of the Winter Solstice at *Paris*. You may with like Ease know the exact Height of the Sun at *Noon*, for any Day of the Year whatever. For if, after having found in the Ecliptic the Place or Degree of the Sun for any given Day, you bring that Degree under the Meridian, you see by how much the Sun declines from the *Æquator*, either on this Side towards the opposite Pole, or on the other Side towards the opposite Pole. If it be on this Side in the Northern Signs, add the Declination to the Height of the *Æquator*, you will have the Elevation of the Sun at *Noon* for the given Day. If the Sun is in the Southern Signs, deduct its Declination from the Height of the *Æquator* above the Horizon.

Hence

Hence it follows, that whoever knows the Latitude, knows the Elevation of the Pole, whose Measure is the same: And that whoever knows the Elevation of the Pole, knows likewise that of the *Æquator*, which is always the Complement or the Difference between the Height of the Pole and 90 Degrees: Lastly, That he, who knows the Elevation of the *Æquator*, knows also the Elevation of the Sun at Noon for all the Days of the Year, by the Addition or Subtraction of its Declination.

Globes are of Service in a hundred other Particulars, of which we must defer the Enumeration to a Treatise of Astronomical Instruments, which I hope hereafter to give you. It was proper, at least, to give you this faithful Account of the most common Helps which we borrow from thence, in order to convince you of the Favours, for which we are beholden to the learned Men of *Greece*, and to *Natural Philosophy*, which has founded these wonderful Machines on the Observations of the Rotundity of the Earth, on the Observation of the Points which bound the Course of the Sun, on the regular Observations of the several Horizons, and the various Elevations of the Pole; in short, on a Series of uncontested Experiments.

THE
Mariner's Compass.
THE
DISCOVERY
OF THE
East and West Indies.

The REVIVAL of SCIENCES.

DIALOGUE V.

EVER since the Time of *Pliny* and *Ptolemy*, Cosmography and the Study of Nature, far from making any new Progress, diminished by Degrees, and at length remained totally neglected. In the first Ages of the Church, the most knowing Christians were too much taken up with the Care of instructing Nations, and of supporting the Gospel against the Heathens, to be able to give themselves over to Studies either less necessary or less important. After having destroyed Idolatry, they turned their Arms against the Disturbers of the Church, who introduced pernicious Novelties into the Faith. On the other Hand, the Liberty, which the *Roman* Armies assumed to themselves,

selves, of creating several Emperors at the same Time, and the intestine Divisions of the Provinces, which took the Party of one Emperor against another, put all in a Combustion, and shook the whole Empire. The perpetual Attempts of the Barbarian Nations to shake off the Yoke, reduced the Eastern Empire within very narrow Bounds, and quite overthrew the Western. After its Fall, the State of *Europe* was long uncertain, and had much ado to preserve one constant Form. The frequent Changes of Masters, Laws, Languages, and Customs, kept Nations in a Kind of Agitation fatal to Sciences and good Taste, which were succeeded by Barbarity and Ignorance.

Afterwards, the Introduction of great Fiefs and Sovereignties subordinate *in infinitum*, held by Fealty and Homage, or with an Obligation of a short Service, completed the Ruin of all. This Form of Government, wherein they fancied they should find a greater Appearance of Liberty and Security, made its Way every where, and multiplied Feuds, together with the Affectation of Independence. There was not a Country Squire, how insignificant soever, who did not lord it, and play the Monarch among his Vassals, and lead them to War against his Neighbours. This Liberty of drawing the Sword in one's own Cause, and of doing one's self Justice between Lord and Lord, together with the unavoidable Wars of the Lords paramount, bent every Mind to War. The wearing of the Sword being thus become the distinctive Badge of Lordship, Lords were no longer seen without it. This Instrument of Wrath accompanied them to their best Friends. They were seen armed even at the public Prayers; and when they united the Title of Bishops to that of Lords, their Swords appeared on the Altar together with the Victim of Peace. The Use of the Sword, by Right residing in the Chief of the State alone, who held it from God, had till then been only precarious and temporary in the Hand of Subjects. That Right, or rather that Commission, was transferable from one Man to another, at the Prince's Will. The Use of it was never given over to the Disposal of any private Man, but intrusted and regulated according to the Wants of the State only. The first Officers had no more the Property or Inheritance of it than our common Soldiers. Since that

Right, originally derived from the Throne, was given in Property as an hereditary Good to a Multitude of Subjects, and was extended to the Subdivisions of the remotest Mesne-Tenures; this Appearance of Petty Sovereignty became the Object of all Wishes. Nothing was thought grand but the Sword: It was in lieu of Learning and Education: It even became the only Science: And for want, not only of Books, but of Tranquillity, Emulation, Applause, and good Examples, Ignorance in all its Branches overspread the World in the most dismal Manner. The liberal Arts and Literature, Eloquence and the Study of Nature, which had, by the Care of *Charlemain* and his Successors, resumed a little Courage, sunk again into a Condition worse than that to which they had been already reduced, by the Barbarity of the *Goths* and other Northern Nations *.

It is true, Churchmen and some learned Princes from Time to Time made useful Efforts towards reviving the Love of Letters. For many Ages together, the holy Precepts of the Church, a few Collections of the noblest Sayings of the Fathers, which were read to the People, and the reading of the Gospel, maintained Faith in its Purity, and preserved the Principles of Integrity among Men: But a false Learning, in some Sort worse than Ignorance, came across the best Intentions, and ruined the Benefit of the best Establishments.

About the middle Ages, a Kind of Learning of a most singular Character overspread all Europe. Though they had in their Hands the Writings of the *Latins* and *Greeks*, which the *Benedictine* Monks had taken Care to copy and multiply; they neglected the Use of the Orators, Poets, and Historians, to exercise themselves merely in *Aristotle's* Philosophy; in which too they laid aside whatever related to the Heaven, the Knowledge of our Globe, Natural History, Eloquence, and that of Mankind. This Part (for what Reason I know not) did not please them at all: They gave themselves passionately over to his Logic and Metaphysics. These cavilling Sciences very likely had an intimate Proportion with their natural Craft and Subtilty. Besides, they needed not, in order

* See Mr. *Phury*. See the Abbot *Goujet's* Dissertation on the State of Science in *France*, &c.

order to attain them, to make any Researches, great Inquiries or Trials; to keep any Correspondences; to have any Books or Instruments; to use Calculations, or give themselves any Trouble. They were extremely pleased with the Thoughts of finding out every Thing in their own Brains, and of acquiring without any Preparatives, and at no Cost, a vast Reputation for Subtilty and profound Learning, by bandying Questions, of which the common Run of Mankind, could understand nothing.

These Philosophers of the middle Age did, indeed, speak upon every Subject: They even thought themselves great Men in Physicks, because they gave Names to, and Definitions of, every Thing, by methodically proceeding therein with the Genus and the Difference. They especially pretended to teach Men how to argue; and this was their chief Skill. Had it not been for their Rules, all Mankind was ready to fall again into its primitive Infancy. But their Categories, their Dialectic, and the subtle Anatomy they made of our Ideas, Judgments, and Reasonings, and of the several Pieces whereof our Discourses consist, were not more fit to teach us the Art of Thinking, than the Anatomy of the Hand, or the Study of the Muscles of the Leg would be, to teach us how to make the Rigadoon Step, or how to handle a Fork with a good Grace. Poor Doctors! who attributed to their Art that which is in Man a Gift from God, and who, by Force as it were, of Machines, caused some Men to do with a dull and heavy Aukwardness, what Exercise and Reflexions every where produced with so much Elegance, Exactness, and Facility.

The same Idleness which made them prefer these empty Speculations to long and toilsome Experiments, likewise made them overlook the Study of Elocution. They even neglected the Decorum of Speech. But Barbarity, which is ever attended with Disgust, is still the least Evil they overspread the Schools with. They accustomed Men to dispute, and of Course to the Desire of being always victorious in the Argument. An Exercise, which was apt to become dangerous, if not moderated with great Politeness, which, under the Pretence of rendering the Learned methodical, made them apt to start Difficulties on every

Subject, eager to reply, and become in a Manner People of another World: Who, instead of sound and serviceable Truths, gave them no Relish for any Thing but Subterfuges, Subtilties, and puzzling, or rather inaccessible Questions; which, far from making them humble, modest, pliant, ready to listen to and assist others, on the contrary made them fond of their own Conceits, always ready to combat the Talents of others, and made them little better than idle Talkers, Men universally useless when out of a Dispute; and by an almost necessary Consequence, fierce, positive, and untractable.

These new Masters, by the Oddness of their Questions, and by the Sourness of their mean, contentious Method, dishonoured the Schools which they had invaded. They every where introduced a dark, sour Kind of Learning, that related to none of those Things which busy Mankind; that was of Service to no Condition of Life, and which, having no manner of Relation to Piety, to Business, to the Sentiments of the Heart, or to Politeness, authorized the genteel Part of the World, not only to forsake them without Regret, but even to blush at being thought to have the least Tincture of Learning.

The Knowledge you have of History, my dear Chevalier, makes you easily guess, that the rough supercilious Philosophers I just mentioned are the *Arabians*, who overspread the Coasts of *Languedoc*, *Italy*, *Sicily*, *Spain*, and *Africa*. The Schools which they established at *Cordova*, in the Kingdom of *Naples*, and other Places, took an Air of being famous, while ours were in a languishing State. What contributed most to the Barbarity of the Method of the *Saracens*, was, that they made it a Rule to neglect the good Authors of *Rome* and *Athens*, which they every where found in our Libraries, thinking, that the reading of these Books, wherein the Names of the Gods were often found, was inconsistent with the Law of *Mahomet*, which they professed: And either from a Motive of Religion, or their own Taste, they confined themselves to the most bombastic, most speculative, and less useful Works of *Aristotle*. The *Latin* Translations, and numerous Comments, which they published of them, spread their Notions and Methods among us: And having since been obliged to abandon all their Posts one after another,

to leave Europe, and shelter themselves in *Mauritania*, did they not carry away all their Subtilties and imaginary Tenets with them. They went to make use of them in the Schools of *Fez* and *Morocco*: But they left among us the Dregs of a false Learning, a Philosophy wholly intellectual, which seemed to have forgot, that we had Eyes to see, and Hands to operate: A Method the more contrary to the Advancement of Physics and Discoveries, because, instead of regulating its Notions on Experience, apd on the perpetual Inspection of Nature, it judged of every Thing from the Nations of *Aristotle*, or of some other Master as little to be depended upon, though of a more modern Date. So long as our old Scholastics quarrelled, without ever looking in Experience for a Solution of their Disputes, Philosophy made no real Progress, except under the Trials of some Workmen. The Necessity of fining Metals for the coining of Money, the casting of Bells and Ordnance; for Goldsmith's Ware, and the Products of the Forges, and for the making of several Kitchen Utensils, at all Times put a certain Number of Men under the Necessity of acquainting themselves, if not with the Nature, at least with the Use of the several Earths, and of all mineral Matters. It may be affirmed, that useful Learning was almost wholly centered among Artificers in Metal, who for want of a Guide, and of good Principles, very often ran headlong into the grossest Mistakes. For Instance, the Sight of the apparent Changes, which happened in these Matters, either disunited or compound, had long introduced this false Notion, that Natures even the most pure and uncompounded, are transmutable, and that a Piece of Iron may, by Means of a certain Preparation, become an Ingot of Gold. Many Artists building on this false Principle, in all Ages made several Efforts, the vast Expence and Inutility of which loaded them with Shame, and both exhausted their Health and Money. However, many of them, as they were working in these fossil and mineral Matters, which obstinately refused the Transmutation so much longed for, by the bye took Notice of the new Effects produced, and lighted upon some constant Compositions, which might be made useful to Dyeing, to Metal-work-

ing, and the Improvement of several Arts. They indeed hunted after a Phantom, but yet they at the same Time were making some Improvements. They traced Nature Step by Step; and this was sufficient to make them find out real Truths and Conveniencies, which sometimes made them Amends for the imaginary Transmutation they flattered themselves with.

The most successful among them was *Roger Bacon*, an English Cordelier *. He was the first who knew the Force of Sulphur and Fire in Conjunction with Salt-petre or Tartar, which gave Birth to Gunpowder, and occasioned the Perfection of Fire-Arms. He seems likewise to have been one of the first, who had any just Knowledge of the Effects of Light, conveyed through a lenticular Glass, or reflected from a smooth Surface, either plain or concave. His Philosophy wholly consisted in observing Nature, and making use of it, by the Assistance of Mathematics. He was in the right Way, and invited every body to follow him therein. But his Superiors, Masters, and Fellow Monks, styled those dangerous Novelties, which they had not learned themselves. He perhaps gave them Offence by superstitious Practices, as he was extremely bigoted to celestial Influences, and all the Nonsense of judicial Astrology. The Studies to be followed, moreover, and the Opinions to be maintained, either in Monastic and Ecclesiastical Societies, or in Universities, were prescribed, as well as the Ceremonial, or the Hour of getting up and going to Bed. Nothing but ill Treatment was to be expected by any that should presume to abandon Aristotle; and the general fixed Rule left no Room either for Researches or Discoveries. The Philosophy of the Arabians, and their tiresome Jargon, remained in Possession of the Schools. Universities have, till the very last Century, hesitated upon having Recourse to Knowledge, grounded on Experience, and justified by Practice. In Convents, very often where philosophical Studies were pursued, the Reader proved much less skilled in sound Philosophy, than the Brother who prepared the Remedies, or took Care of the Kitchen garden. Even now in several

* He died at Oxford in the Year 1284.

several provincial Schools; if they employ three or four Hours in cursorily shewing a few Experiments on *vacuum* and the Elasticity of the Air; they in Return employ seven or eight intire Months, in leisurely treating of Matter and Form, never forgetting Privation, nor substantial Form, nor the Appetency of Matter for all Forms; nor chiefly the modal Intercession, as a distinct Entity between Matter and substantial Form.

Though the *Arabians* did thus very much injure Mankind, by rendering Knowledge hateful on Account of the Barbarousness of the Language; and especially by smothering, for several Centuries together, the noblest Talents; and the best Genioses, by an Habit of always exercising them upon idle Notions, which could be of no Use in the World; yet must we not refuse to give a few of these *Saracen Doctors* their Due. Some of them raised themselves above the common Level, pursuing useful Studies. Some applied themselves to *Physic*, and that Study has since their Deaths, perpetuated itself in more than one of their Posts; for Instance, at *Salerno* in the Kingdom of *Naples*, and with far greater Success at *Montpelier*; which was raised upon the Ruins of *Maguelona*, one of their best Establishments. We are beholden to the *Arabians* for the Figures of our modern *Arithmetic*, and the Use of *Algebra*, if they be not even the Inventors of the latter. Some of them, caressed and made much of by the *Egyptian* and *Babylonian* Caliphs; cultivated *Astronomy*, measured the Circuit of the Earth, translated into their own Language, and communicated to *Europe* *Ptolemy's* Books *, together with the Use of the *Astrolabe* or flat Sphere, and of several other very ingenious Machines, all the Pieces whereof still go by *Arabian* Names, though they only shewed the Use of them, and the Invention was due to the *Greeks*.

The Emperor *Frederic II.* in the thirteenth Century, caused *Ptolemy's* great Construction to be translated from the *Arabian* into *Latin*: Which enabled a Professor † of the University of *Paris* to write a Work which was much admired; and made use of every where, upon the Sphere.

Alphonso,

* In the Year 813.

† *Sacro Bosco*, a *Matiburini* Friar, who died in the Year 1256.

Alphonso, King of *Castile* *, employed several learned Men in reforming Astronomy, and became himself a very good Astronomer. In the next Century, *Charles*, surnamed *the Wise*, though wholly taken up with a much more necessary Science, I mean the Government of his Kingdom, persuaded *Pisan of Boulogne* to come to *Paris*, rewarded generously the Works of *Nicolas Oresme*, and founded several Professorships for Mathematics †. But these solid Studies supplying no Matter for Dispute, which was then the reigning Taste, they were always very languidly pursued; and, what was still worse, the *Saracens*, who had introduced them to us, had mixed them with all the Poison of Astrology; so that their Acquaintance was hurtful to us in all Respects.

While the finest Geniuses exercised themselves in this trifling Manner on Generalities, that were of no Sort of Service to the Pulpit, the Bar, the Government of States, or even private Families; a Kind of Hazard, or rather a special Providence, caused a Phænomenon to be observed, the Discovery of which has procured us the Knowledge of the new World, the new Way to the *Indies*, and such a Progress of Sciences, as had never yet been attained to.

The Load-stone, in all Ages, was known to have had the Property of attracting Iron. *Thales*, amazed at so constant an Effect, thought that Stone had a Soul. *Plato*, *Aristotle*, and *Pliny*, have mentioned the same Attraction: But neither they nor any other Philosophers, till the eleventh, or even to the Beginning of the twelfth Century, knew, that the Load-stone, suspended or swimming by Means of a Piece of Cork on Water, always turns one of its Sides, and constantly the same, towards the North. Even the Man who made this Observation stopped there, and understood neither the Importance nor Use of his admirable Discovery.

These two Properties of attracting Iron, and of being constantly directed Northward, being once known; some Virtuosoes repeated the Experiments; and making a

Piece

* In the Year 1270.

† At the College of *Maitre Gervais*.

Piece of Iron and a Load-stone to swim in a Vessel full of Water (having first put them on Pieces of Cork, that they might move one towards another without any Obstacle) they observed, that when the Piece of Iron had been rubbed against the Load-stone, that Iron had also the Property of turning towards the North, and of attracting Needles and Iron Filings, as well as the Load-stone itself. From one Experiment to another, they came to lay a Needle touched with the Load-stone on two small Bits of Straw floating on the Water, and to observe, that the Needle invariably turned its Point towards the North. They were in the Way of making the great Discovery: But this was not yet what we call the Sea-Compas.

The first Use which Virtuosoes made of this Discovery, was to impose upon simple People, by an Appearance of Magic. For Instance; a little hollow Swan of Enamel, swimming by that Means on the Water of a Vessel in which it was put, and having in his Bill a little Iron Serpent, or Lizard, never failed to run after a Piece of Bread offered him on the Point of a Knife: It faithfully followed the Motions of the Knife backward and forward, and gave the utmost Surprize to the Spectators, who were ignorant, that the Knife had, by the Touch of the Load-stone, acquired the Property of attracting Iron. The pretended Magician fully convinced them of his Power, by ordering a Needle, laid on the Surface of the Water, to turn its Point from the East to the South, and bring it towards such or such a Point, as towards the Polar Star; which was immediately obeyed.

A Genius of a more serious Turn at last applied this Experiment to the Wants of Navigation; and a Poet * of the twelfth Century informs us, that our French Pilots made use of a Needle touched with the Load-stone, which they called † *La Marinette*; because that Stone being several Times rubbed the same Way, and on the same Side, upon an Iron Needle, communicated thereto the Virtue of turning towards the unmoveable Star, which we call the Polar Star, and which was a Rule for Seamen in cloudy Weather.

Icello

* *Guyot of Provins*, who was at the Court of the Emperer Fr^{er}eric, held at Mentz in the Year 1181.

† See Abbot Ursperg, and Faucher's *Antiq.*

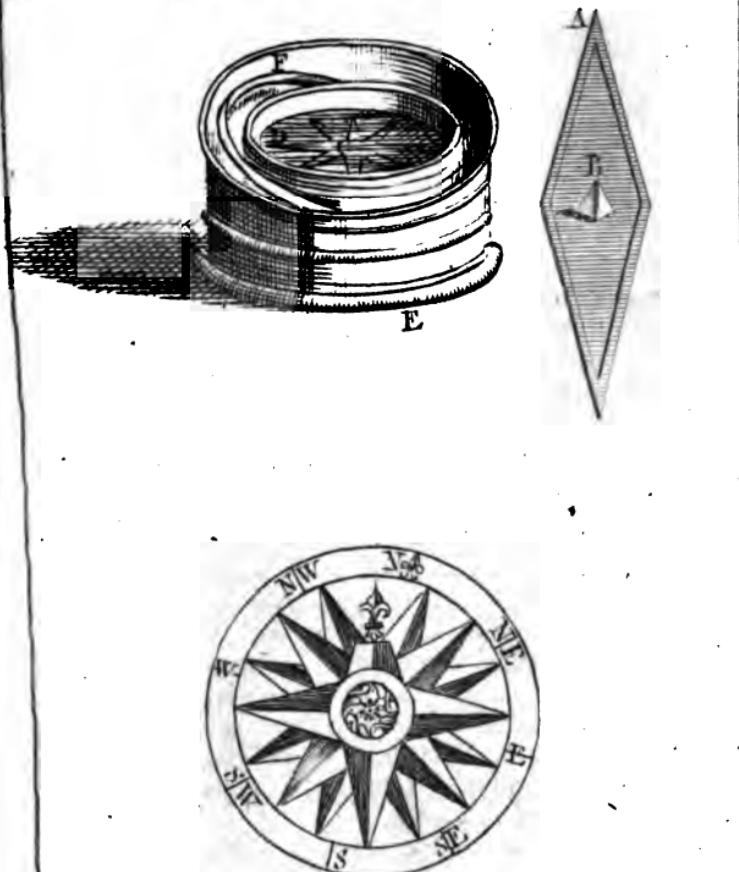
*Icelle étoile ne se meut,
Un art font qui mentir ne peut,
Par vertu de la Marinette,
Une pierre laide, noirette,
Où le fer volontiers se joint, &c.*

Soon after, instead of laying the Needles (as they did then) upon a Straw or a Piece of Cork, on the Surface of the Water, which the Motion of the Vessel always tossed about too much; an understanding Workman bethought himself of suspending on a Pivot, or on a moveable Point, the just Middle of a Hand touched with the Load-stone, that balancing and playing at Liberty, it might yield to the Attraction, which always directs it towards the Pole. At length, another Workman thought of charging that Needle with a small and very light Circle of Paste-board, whereon he had delineated the four Cardinal Points, together with Lines representing the chief Winds. The whole being divided into the 360 Degrees of the Horizon. This little Machine lightly suspended in a Box, which was itself suspended much like the Seamens Lamp, perfectly answered the Hopes of the Inventor; because, by directing the *Flower-de-luce* towards the North, it kept all the other Points of the Rose, correspondent to the Points of the World by them represented. And though the Vessel might have changed its Situation ever so much, yet the Needle, constant in its Return towards the North, always shewed by the Points of the delineated Figure, the Part of the World towards which they sailed, and the Winds they were to avoid.

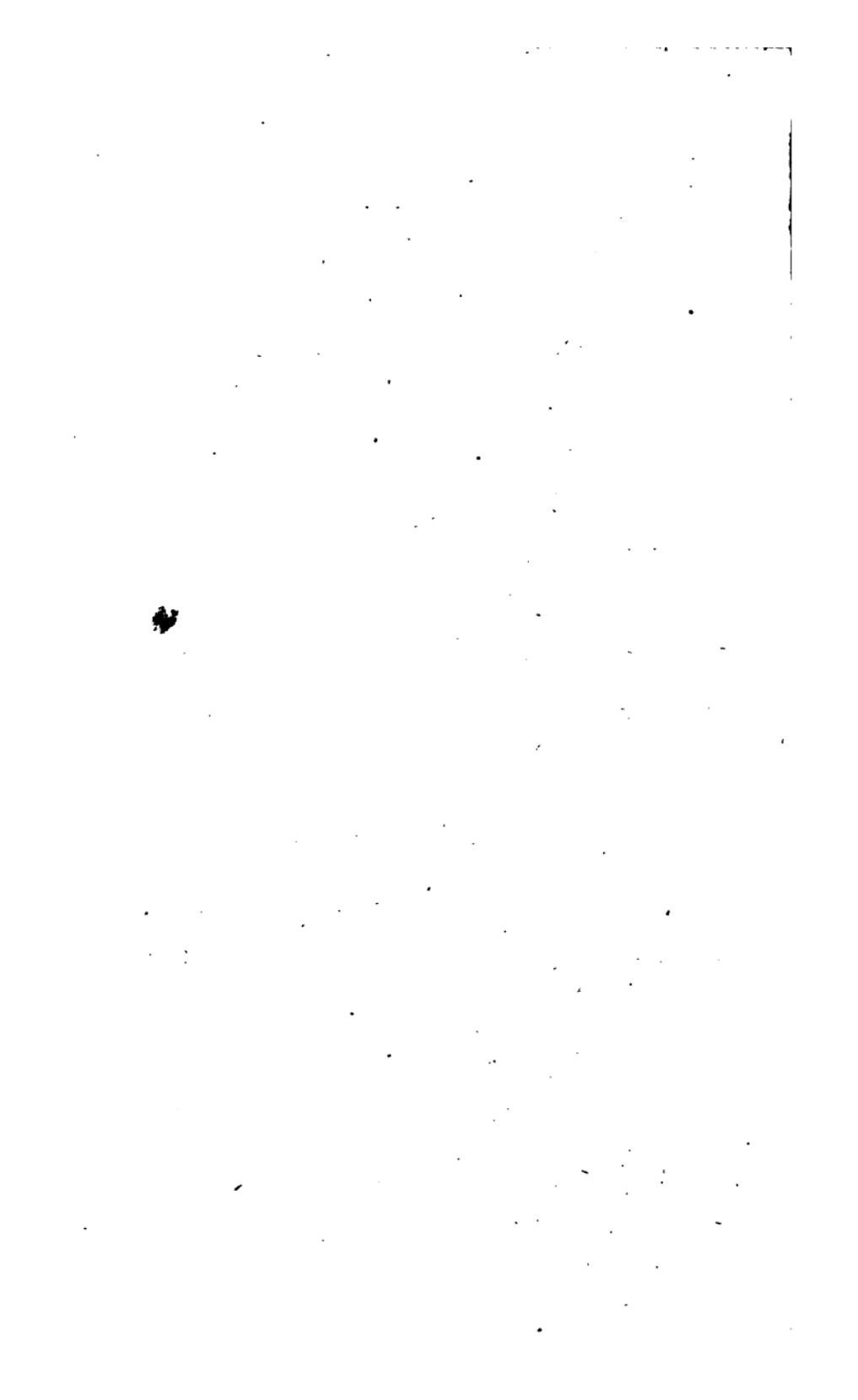
But it is with this Invention, as with that of Mills, of Clocks, and the Art of Printing. The Name of the Inventor is not known, because many had a Share in the Discovery. These Things were found out only in Parts, and brought by little and little to a greater Degree of Perfection.

From this it is plain, what we are to think of the Dispute still subsisting between several Nations which claim the Invention of the Sea-Compass. The Italians are positive, that in the Year 1302, *Flavio Gioia* constructed the very first Sea-Compass that was ever seen, at *Melphi* in the King-

The Sea-compass.



A. The needle touched with y lead-pine, upon w. y land of y winds is observed. B. The compass box or instrument needle upon a pivot w. stands at bottom of a lantern w. C. The land of y winds. D. The horizontal border w. changes its situation as y ship changes heres, whilst y needle remains fixed to y North. E. The Box. F. several circles suspended one within another, upon pivots that cross each other. The innermost is horizontally fixed by a London-Cap that weighs downward.



Kingdom of Naples. The French are very far from submitting to this Judgment. They say, that the Use of the Needle rubbed with the Load-stone, for the regulating of Navigation, is from History proved to have been among them even in the twelfth Century. They add, that if a *Flower-de-luce* is for a Mark of the North, either in the moveable-Paste-board, which Seamen put in the Style, or in the Card of the Winds, which is fastened under the Pivot of the Style, at the Bottom of fixed Sea-Compasses; it is because all Nations have copied it from the first Sea-Compasses, which came from the Hands of a French Artificer.

The English attribute to themselves, if not the Discovery, at least the Honour of having brought it to Perfection, by the Method of suspending the Box where the Needle touched with the Load-stone is. They alledge in their own Behalf, that it is from them all Nations received the Names given the Sea-Compass, on receiving from them that Machine, reduced to a commodious Form: That it is called (*Compas de Mer*) from the two English Words *Mariner's Compas*; and that from their Word *Boxel*, which means a little Box, the *Italians* made their Word *Bussola*; just as they change the Name of *Alexander* into that of *Alessandro*.

Others are no less zealous to persuade us to give the *Chinese* the Honour of it. But as the Needle, touched with the Load-stone, is as yet no otherwise used in *China*, than as it is made to swim on a Piece of Cork, as they formerly did in *Europe*: It is to be supposed, that *Marco Polo*, or some other of the *Venetians* * who went to the Indies and *China* through the *Red Sea*, did, in the thirteenth Century, convey this important Experiment into the very Heart of *Asia*; the Use of which was afterwards perfected among us by several Pilots.

The Needle rubbed with the Load-stone, besides its constant Direction towards the North, has yet two other Motions: The one of *Declination*, by which it deviates a few Degrees from the true Meridian, or from a Shadow of the Sun at Noon: The other

The Declination and Inclination of the Needle.

* See *Orbis novus*.

other of *Inclination*, by which it lowers towards the Earth its Northern Point; as if that Point was heavier when rubbed with the Load-stone, which obliges it to charge the Southern End of the Needle with more Weight, in order to keep it Horizontal, and in perfect Equilibrio.

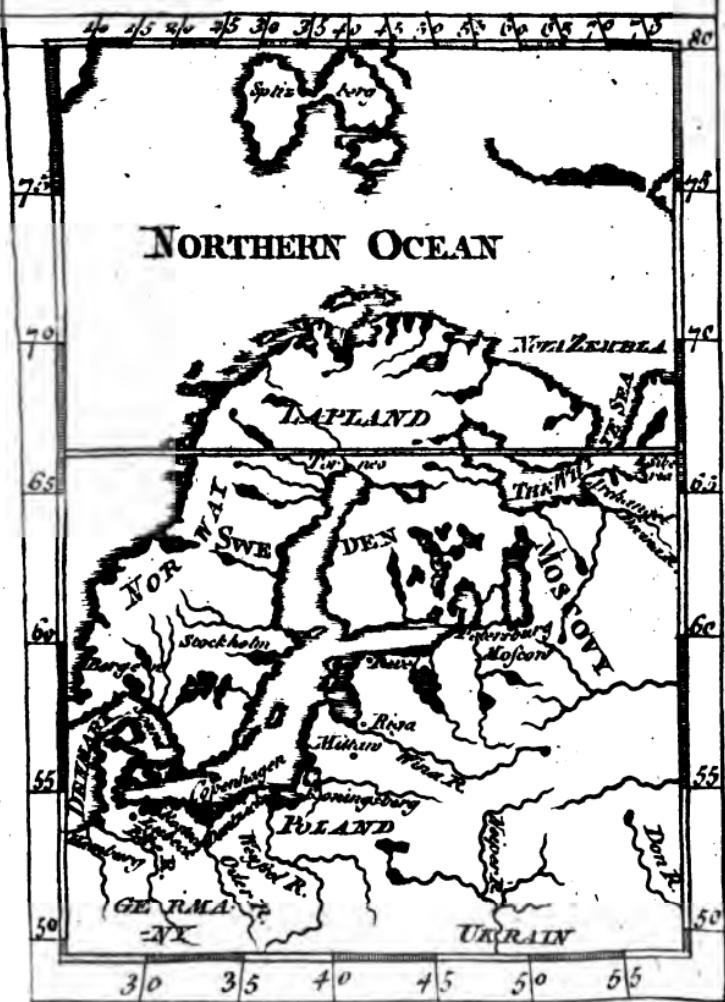
From the Knowledge of the Quantity of that Declination, which is much the same from Year to Year, and sometimes for many Years together, they take all previous Cautions, to have it adjusted as if it did not decline at all. As to the Inclination, though the Knowledge of it has been hitherto unfruitful; we still hope, that the Regularity of it will one Day or other be applied to some profitable Use.

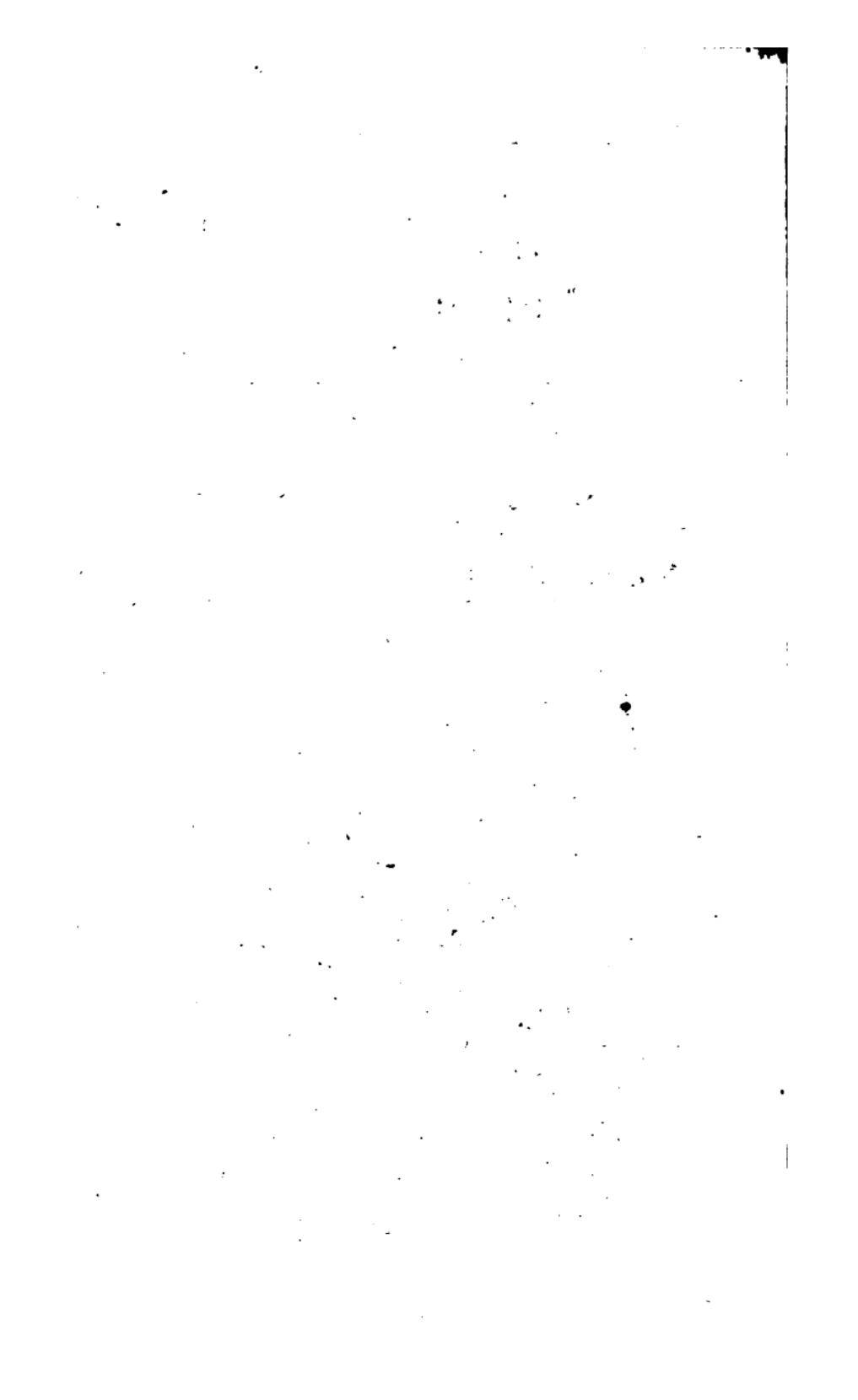
The best Con- Great Naturalists are much divided, on-
jectures con- the Causes of these several Directions of-
cerning the the Load-stone. But there is a Truth in-
Cause and Di- finitely more obvious to me than all their-
rections of the Systems, *viz.* That God has spared us
Needle, much Toil and Labour, and saved us
from many dangerous Inadvertencies, by granting us the
Use of Things, without letting us into the Structure and
Reason of them.

The Cause of the Direction of the Load-stone, as well as all other secret Springs of Nature, is concealed from us. But we know the Uses to which they may be applied, and that Science is of more Advantage to us than the Knowledge of the Cause itself. The Knowledge of Causes would make unactive Philosophers, who could never be brought from their sublime Speculations to the Government of Things here below. The bare Knowledge of the Directions of the Load-stone carries us from one End of the Earth to the other. A Sea-Compass worth Half a Crown, may bring into our Ports the Productions of the four Quarters of the World: And it is really from this Invention, brought to its Perfection in the fourteenth Century, that we may date the Renewal of Geography, Trade, Natural History, and true Physics.

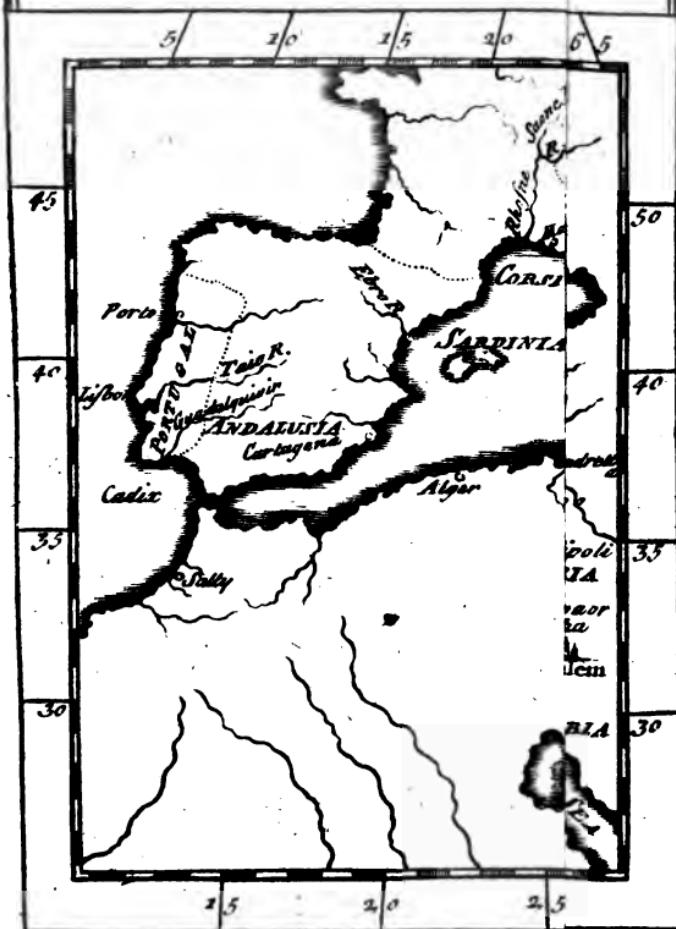
The ancient Pilots of *Marseilles* and *Pisa*, the Commerce of *Gendes* and the *Venetians*, by the Assistance of Europe, of this admirable Instrument, in the fourteenth and fifteenth Centuries, carried on a very profitable Trade at *Tripoly in Barbary*, at *Japba*, at *Damas*,

THE NAVIGATION. of the NORTH





MEDIT



by the Way of *Tripoly*, in *Syria*; at *Aleppo* by the *Alexandretta*, at *Famagouſte* in *Cyprus*, at *Smyrna*, in the Sea-ports in the *Levant*; whence they rend spread all over Europe Cotton, Opium, Rice, &c, Drugs, and other Commodities of *Asia*.

Use of the Sea-Compaſſes promoted The Commerce
couraged, in a Manner quite different from that of former Ages, all the
Towns.

Trades of the Merchants of *Berghen* The Commerce
way, of *Stockholm*, *Riga*, *Dantzic*, *Rofloc*, *Lubec*,
& *Hamburg*, and of all the great *Hanſe*, or *Aſſoſon*, which was formed for the Commerce of the *Baltic*, and of all the North. But the finest Trade of

Times was that, which the *Venetians* The Commerce
led on at *Alexandria* and *Cairo*, of the Commodities which the *Arabians* and *Eastians* fetched from the *Indies*, and from

the East through the *Red Sea*. The Profits they made by their Cotton, Silk, Gold, Pearls and Jewels, were immense: But Spices and Grocery Wares were the finest branch of their Commerce. They were the only Distributors of them: And at that Time no Dainty was thought, at the nicest Tables, superior to that Production of *Indus* and the *Molucca Islands*. Sugar was little, or scarcely known at all in *Europe*: But Spices began to be there the chief Ornament of great Feasts. They thought nothing was fitter to be presented to Judges after the Decision of a Law-suit. At Nuptial-feasts the Bride distributed Spices to all the Assembly; and Universities, in their Rejoicings, had in this conformed to the Use of the *Beau Monde*. That Commodity always went off very well, and every one knows how far the Art of Cookery has carried the Use of them.

The Prosperity of the *Venetians* awakened the Emulation of the Inhabitants of the Coasts of the Ocean. Most of them made Attempts either themselves to reach the *Indies*, or to discover some new Coasts, where they might trade with Profit. The Facility of avoiding the Shelves and Shallows by taking Sea-room, and of finding their Way in again by the Direction and Advices of the Sea-Compaſſe, filled these two Ages with extraordinary Adventures,

tures, and with Discoveries more lucky than were expected.

The Discoveries
of the Normans.

The *Normans*, a laborious and persevering Nation, and capable of every Thing, were the first who discovered *Guinea*, and the *Canary Islands*, the Remembrance of which had been a long Time lost. We still find in *Guinea* the *Little Dieppe*, where the Inhabitants of *Dieppe* had lodged themselves from the Year 1364: and several other Names testify the antient Settlements of the *French* on the Western Coast of *Africa*. They abandoned them in the Year 1410: But the Natives preserve the Memory of them, and still regret the Sweetness of their Commerce. These Settlements would still have subsisted, or have been renewed and embellished, had the Government assisted them, and preferred, as they now do, true Politics, which are the important Affairs of the Commerce and Repose of the Nation, to those glittering Projects which make the People miserable, in order to give them a Proof of the Minister's Capacity.

Ivory, which the Inhabitants of *Dieppe* brought from the *Tooth Coast*, gave Birth to the Establishment of the Manufactures of Ivory Ware, which inriched the City of *Dieppe*, so long as that Matter continued in the Esteem of the Public.

The Discove-
ries of the Por-
tuguese.

The *Portuguese*, being obliged by the Smallness of their Territory to look out for Means to extend it, and seconded by the advantageous Situation of *Lisbon* and *Oporto*, were those who had most at Heart the finding out of a Passage to the *Indies*, other than by the *Red Sea*. During the whole fifteenth Century, the Kings of *Portugal* were most earnestly taken up with that Project. They sent People to visit all the Western Coast of *Africa*. Their Pilots found out *Madira* in the Year 1420, or thereabouts. The Colony they sent thither, set on fire the Forest which covered the whole Island, and made it a good Establishment, where Plenty actually reigns, together with all the Politenes of *Lisbon*. In the Year 1449, they peopled the Island *Tercera*, and the other *Azores*, which some *Flemings* had first observed, and which were uninhabited. These first Successes encouraged the *Portuguese*: They soon after made themselves Masters of the *Cape Verd Islands*,

Islands, less fruitful indeed than the other, but useful for the Salt and Goats which they found there. They discovered the *Cape Verd* *, which is next to them, between the Rivers *Senegal* and *Gambia*. They settled themselves on the *Golden Coast*, fortified themselves in several Places of *Congo*, from the River *Zaire*, which washes that Kingdom, to the River *Coanza*, which crosses the Kingdom of *Angola*. They have ever since been, and still are in Possession of the whole Commerce of the two last Countries. Though Barterings were very advantageous on all these Coasts, the great Aim of Pilots, and the Wishes of the Court were, to find out a Passage to get into the East. But they were barred by a Coast which has no End. They carried their Researches to 33 Degrees of Southern Latitude, to which you need only add the 40 Degrees of Northern Latitude, which is the Situation of *Lisbon*, whence they set out, and you will have the Length of their Course, which thus proves to be above 1800 Leagues before the Discovery of that Passage.

They had lost all their Hopes, when being arrived to the 34th Degree of Southern Latitude, they at last found, that by keeping along the tedious Coast of the *Cafres*, they advanced towards the East, and even could go up again towards the North, by coasting round *Africa*. In the Year 1487, they brought to the Court of *Portugal* the agreeable News of the Facility of trading round that great Continent, and of doubling the Cape, which terminates it towards the South. They began to have better Hopes than ever of making a Discovery of the *Indies*: And the Cape, which opened them a Passage to them, was on that Account called the *Cape of Good Hope*.

Even before this Discovery, so much wished for by King *John II.* one *Christopher Columbus* † a *Genoese*, a great Navigator, and the best Geographer of his Time, had made it his chief Business to enter into all the Views of that Prince, as he was in his Service. He thought he might with good Reason give his Prince to understand, that there was a better Way to arrive at the *Indies*, than that which was sought for him by the Extremity of *Africa*: That in *Ptolemy's Maps* ‡, the Eastern Lands of *Afrix* reached

* Some place this Discovery three Years sooner.

† The Project of *Columbus*. ‡ See the Map.

reached to the 108th Degree of Longitude, and were not yet limited: That very likely they extended still a great Way into the 180 Degrees of the other Hemisphere: That they might perhaps prove to be very near the Western Coasts of *Spain*: That without passing through the Hands of the *Egyptians*, as the *Venetians* did, without undergoing the Rains of the Tropics twice, and the Heats of the whole Torrid Zone, as those did who attempted the Passage round the Extremity of *Africa*, they needed only take their Course by the Help of the Sea-Compass cross the Western Ocean; and that by patiently keeping near the same Latitude, they, without leaving the Temperate Zone, would arrive either to *China*, or to some other Parts of *Asia*, the Commerce of which would be the Property of his Majesty. Such was the Project of *Columbus*, and far was it from wanting Likelihood.

It is true, the Eastern Coast of *China*, according to the Accounts of the Moderns, does not extend beyond the 140th Degree of Longitude; and *Columbus* lengthened the Coasts of *China* according to his Wishes, and brought them, in his own Idea, near the Coasts of *Spain*, in the other Hemisphere, though these are indeed 220 Degrees, that is, Two-thirds of the Globe *, distant from them. But though the Inspection of *Ptolemy's Maps*, upon which they did then depend, seemed in something to favour the Hopes of *Columbus*; the King did not approve them, and would not venture his Men and Ships on bare Conjectures.

Columbus went to offer his Services and Projects to *Ferdinand*, King of *Castille*. That Prince, after having hesitated, at last ventured an Advance of 17,000 Ducats and three small Vessels. Add to this twenty Men, and the Provisions of a Year; and these are all the Preparations which procured *Spain* the Riches of the new World.

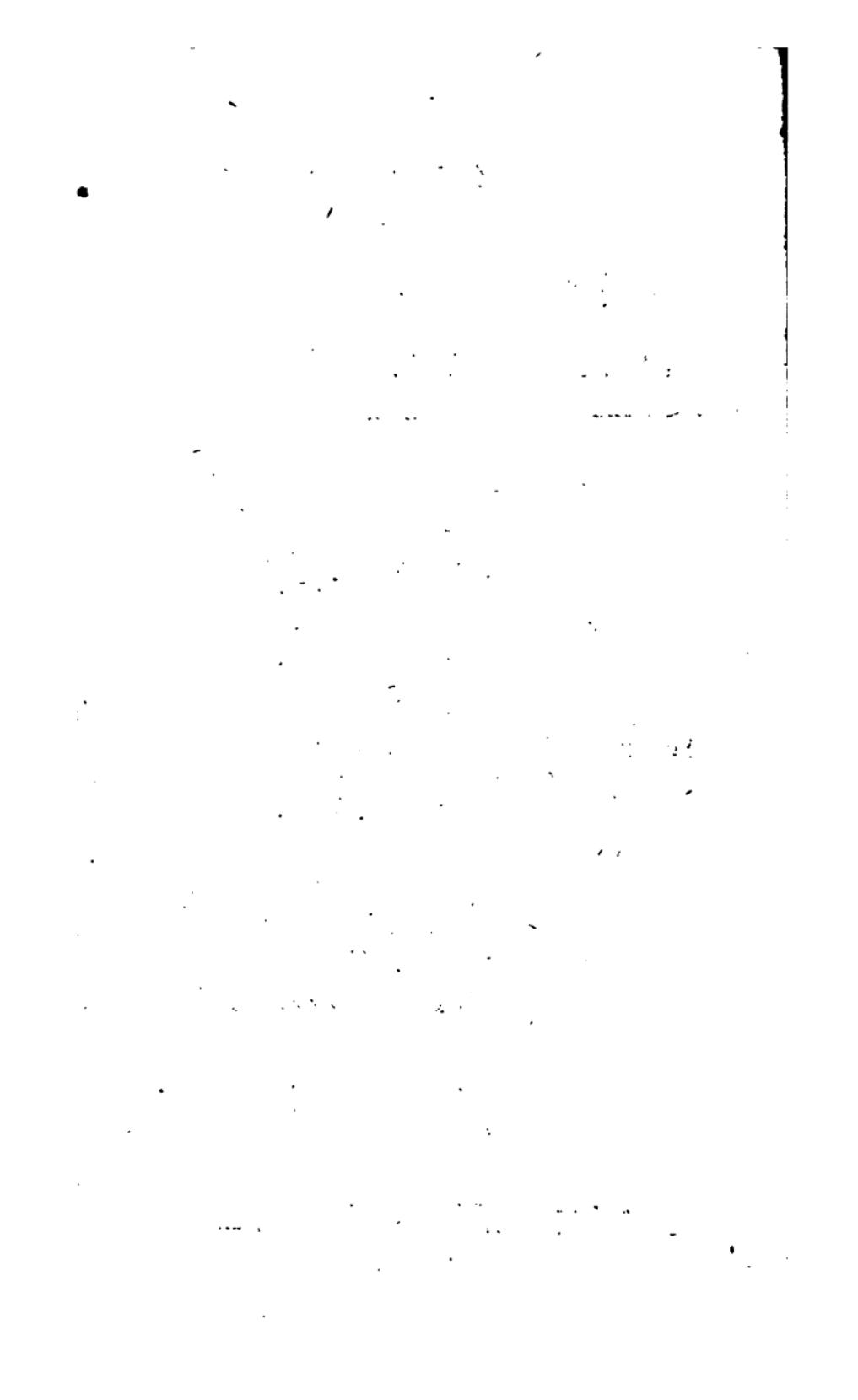
The new Admiral set out on the 3d Day of *August* of the Year 1492, from *Palos*, a small Port of *Andalouſia*. After many Vexations, Troubles, Seditions, and Dangers, he had the Satisfaction to see Land the first: And instead of touching at *China*, or any other Coasts of *Asia*, he landed at one of the *Lucca Islands*, almost 4000 Leagues distant from the Coasts of *Asia*. He afterwards discovered

the

* See Mr. *De l' Isle's Globe*.

THE COLONIES OF THE EUROPEANS IN AMERICA.





the *Greater Antilles*, viz. *Cuba*, *Hispaniola*, or *St. Domingo*, *Porto-Rico*, and *Jamaica*: Then the *Lesser Antilles*; and after having opened the Door of a new Continent, he brought from thence to *Spain*, *Gold*, *Fruits*, and several other Productions. He was forced by the Winds to take his Course through the River *Tayo*. He by the Way saluted the King of *Portugal*, and had the fond Pleasure of shewing him by Effects the Success of a Project, which had been rejected by that Prince. Some of his Courtiers were for making away with a Man, whose Counsels were going to inlarge the *Spanish Monarchy*. But the King with Dignity replied, that the Services done the King of *Spain* were no Crimes; he, with Horror, rejected the Proposal, and caressed Merit, though it was become useless to him. *Columbus*, on the 13th of *March* 1493, went from *Lisbon* to *Palos*, where *Ferdinand* expected him. He entered the City in Triumph, with the Sound of Bells, and the Acclamations of all the Inhabitants. Soon after, he went again to the new World, with seventeen Ships, provided with all the Supplies necessary for the settling a powerful Colony. He did not succeed till he had been very often crossed by Envy, by false Reports, and by the Partialities of some certain Geniuses full of Self-conceit, and always ready to decide positively what they have not the least Knowledge of. The Love of Voyages and Enterprizes became the universal Taste: But most of those who made themselves known to the new World by these Voyages, being led thither by Avarice, proved Monsters of Ingratitude, Injustice, and Cruelty.

Americus Vesputius, a *Florentine Merchant*, went as a Passenger, or only as one concerned in the Undertaking, with a Fleet which set out in the Year 1499. He had Occasion to visit some Countries, and to be a Witness of some Expeditions. But though he was without Titles, and had hardly seen any other than the Countries where *Columbus* had been before, he published several Accounts, wherein he attributed to himself the Discovery of *Terra firma*. His Babbling imposed upon the People and the Court. He was doubly unjust towards *Columbus*, by contributing to deprive this great Man both of his Employments and Liberty, and by robbing him, by his Tricks,

Tricks, of his Reputation, and giving his own Name to the Continent, which *Columbus* had discovered.

Fernando Cortez, assisted and guided by the Knowledge of *Griaba*, subdued to the King of *Spain* the rich Country of *Mexico*, which affords *Gold*, *Indigo*, *Tobacco*, *Cocoa*, and *Cochineal*. *Pizarro* took the Opportunity of the Divisions of the *Incas of Peru*, to insure to himself the Possessions of that Country so abundant in *Gold*, and still more rich by the prodigious Revenue of the Silver Mine of *Potosi*. To both these Conquests, which procured the *Spaniards* the two finest Parts of *America*, they addod many great Settlements in *Chili*, the golden Mines whereof are the most esteemed in the whole Universe, along the River of *La Plata*, the adjacent Countries to which are fruitful as far as *Buenos Ayres*, and in *Terra firma*, where they find the *Cocoa* of *Carracos*, and the *Tobacco* of *La Verina* near *Comana*.

The State of *America* has by Degrees, and after many Vicissitudes, at last taken a constant Form. The Coasts of *Brazil* are become the Lot of the *Portuguese*, who continually draw from thence the most perfect *Sugar*, *Tobacco*, *Gold*, *Jewels*, and *Brazil-wood*, which is employed, like the *Fir-tree* of *Japan*, in red Dyes, and in Works artificially turned.

The inner Parts of *Brazil*, the *Magellanic*, and the adjacent Countries of the large River of the *Amazons*, hitherto have excited the Delires of none of our *European* Nations, either on Account of the Barbarousness of the Inhabitants, who still are *Anthropophages*, or on Account of the little Value of their Productions.

From the Isthmus of *Panama*, which joins *North America* to *South*, the *Spaniards* are in Possession of the Coast of *Terra firma*, to the Mouth of the River *Oroonoko*. Other *European* Nations, hitherto not very curious of knowing the Heart of the Country, are contented with their Settlements on the Coasts, from the River *Oroonoko*, to the River of the *Amazons*. The *Dutch* live at *Surinam*; the *English* at *Maroni*; the *French* at *La Cayenne*, and the adjacent Countries.

The immense Rivers just-mentioned, have their Supplies from the long Rains of the *Torrid Zone*, and in the proportionable Reservoirs, which are in the Bowels of the *Cordilleras*, the highest Mountains of the Universe, which form

form a Ridge of above 1500 Leagues, from the Isthmus to the Straights of Magellan.

The fine Establishments of the French and English, are wholly in North America. The English Colonies. The English are there possessed of an Extent of Land above 700 Leagues in Length, on the Eastern Coast. The Island called Newfoundland, which became their Property by the Treaty of Utrecht, puts them within Reach of the Cod fishing on the great Bank or Shelf; but still without excluding other Nations from it. Acadia, which the same Treaty has secured to them, has conveied into their Hands a great Part of the Commerce of Castors, which we had with the People of Canada. New England, New York, Pennsylvania, Maryland, Virginia, and Carolina, altogether are all overspread with English Families, which, together with the Natives and the Negroes which have been transported thither for the Culture of the Lands, form many strong and flourishing Colonies. The English are also Masters of Jamaica, and some of the smaller Antilles. The Island of Barbadoes alone, though it be not 25 Leagues in Circuit, maintains almost 60,000 Inhabitants. I should have said 100,000, reckoning the Negroes, were it customary in Enumerations to reckon the Beasts of Burden. The chief View of the English is to draw from their Colonies Mafts for their Ships, their small Timber and Wood for their Buildings and Vessels, rather than always to be obliged to go and buy them in the Wood-yards of Hamburg, or in the Forests of Sweden.

The French Colonies likewise are partly in the Continent, and partly in the Islands. The French Colonies. Above an hundred thousand French cultivate the Banks of the River St. Lawrence in Canada, and there live in Plenty, by Means of the Corn, Vegetables, and Woods which their Lands afford; but above all, the Castor or Beaver, and other Furs, in which they trade with the Savages, by Exchanges of Stuffs, Goods, and all Iron Wares, which they fetch from France, or from the Country itself.

The Louisiana or Florida, a vast Country, watered by the River Mississippi, and by a Multitude of other Rivers, begins to yield the French more than bare Promises. It

offers them on every Side Lodgings on an Extent of above 1800 Leagues : It presents them every where with Fir-trees, Beech-trees, Oaks, and Walnut-trees, that is, with the finest Woods for Veneering and for Framing ; the delicious Fruits of hot Countries, together with the Vegetables and Corn of *Europe*, which they cannot be without. Whatever is carried to that Country, thrives there : The small and large Cattle live there as well as in our own Pastures. Horses and other Beasts of Burden, which multiply very easily, afford the Inhabitants Services less dangerous than that of the Negroes, and far more agreeable to Humanity. But who shall persuade our rambling Families to leave their Dunhill, and go and live honourably in that happy Country ? If at least the Children of those who have no other Profession but Beggary, were transported thither when young, they would soon forget a Country scarce ever known to them. In these new Colonies they would prove useful Subjects to the State, and not perpetuate among us a Party of idle Fellows, a Breed of profligate Villains, whom we fatten out of Charity, and encourage by our Bounty to be good for nothing.

We have other Establishments which improve every Day. Out of the Remnants of our Colony of *Acadia*, was formed that of *Cape Breton*, over against the Mouth of the River *St. Lawrence*. The great Island of *St. Domingo*, which we share with the *Spaniards* ; the Island *Martinico*, and many other small *Antilles*, which are now our Property, supply us with Tobacco, Cocoa, Rocou, Vanille, preserved Fruits, and, what is still more useful, with Cotton and Sugar.

The Sea-Compass, which has opened all those rich Countries to the Nations of *Europe*, has likewise rendered Whale-fishing easy to them, throughout the North. It has guided the *English* to the Bottom of the *White Sea* ; and by the Discovery of the Port of *Archangel*, it imparts to the most Northern Nations of *Europe* all the Productions of the South ; in Return for which, it brings back to us the Marten-skins or Sables, and all the Furs of *Siberia*, *Isinglass*, Tar, Sena, the best Rhubarb, and many other useful Drugs, which, like the latter, are scarcely to be found any where but in *Tartary*.

When

When the Spaniards, instead of conveying us to *China* and the *Indies*, as they designed, had found out *America*, which they had not the least Suspicion of, the Portuguese, sorry to see in other Hands what had been offered to them, resumed their first Project of getting to the *Indies*, there to find an Equivalent. They in Effect arrived thither by doubling the *Cape of Good Hope*, and by causing themselves to be directed by some Pilots, whom they took on the Coasts of *Mojambique* and *Mombaxi*. *Vasco de Gama* had the Honour of landing at *Calicut*, on the Coast of *Malabar*, in the Year 1497. The Portuguese under his Conduct, and afterwards under that of the great *Albuquerque*, made all the East tremble with their new Artillery. They made themselves Masters of *Ormus*, at the Entrance of the *Persian Gulph*, and thereby Masters of the Commerce of the Pearls at *Catif*, and of the finest Commodities of *Perisia*. They invaded *Diu*, *Goa*, *Cochin*, the Pearl-fishing at *Cape Comorin*, and the finest Ports on the Coast of *Coromandel*. They built Forts every where; at *Bengal*, at *Sumatra*, and in all the *Molucca Islands*. They conquered the Island of *Macao* next to *Chiba*: By which Means they usurped the Property of the whole Commerce of the *Venetians*. They even carried it on with a greater Benefit, having every Thing at first Hand; and alone supplied *Europe* with Varnishes, *China Ware*, and Silks of *China*, *Tonquin*, and *Cochin China*; the Cloves and Nutmegs of the *Molucca Islands*; the Pepper of *Sumatra*, and of the Peninsula of *Indus*; the precious Stones of the old Rock of *Pegu*, *Ava*, *Golconda*, and *Visapour*; the Cotton, Silk-stuffs, and Carpets of the *Mogul*, and the adjacent Countries; the Cinnamon, or Bark of the Cinnamon-tree of *Ceylon*; the Pearls of *Cape Comorin*, and chiefly all the Gold of *China* and *Indus*. Never was Fortune more favourable to them; for which Reason the Reign of *Emanuel*, the Successor of King *John II.* was called the *Golden Reign*.

The greatest Misfortune that ever happened to *Portugal*, was their being reduced to a Province of *Spain* under the Reign of King *Philip II.* in the Year 1580, and remaining in

that State to the Year 1640, which was the Year of the Restauration of the Family of *Braganza* to the Throne of *Portugal*. The *Dutch*, who during that Interval did all their Endeavours to shake off the Yoke of the *Spanish* Kings, and were not acknowledged as a free Country by *Spain*, till the Peace of *Maastricht* *, found no other Resource than in the Commerce of the East, when *Spain* and *Portugal* had shut up their Ports to them, by which they lived before. They every where treated the *Portuguese* as *Spaniards*: They took their Commerce and their best Settlements from them; so that the *Portuguese*, dispossessed of all, and reduced in the East to almost no other Places than *Macao* and *Goa*, had lost the chief Supports of their State, had it not been for the Commerce of *Africa*, and the Conquest of *Brazil*, which comforts, and perhaps fully makes them Amends for their Loss.

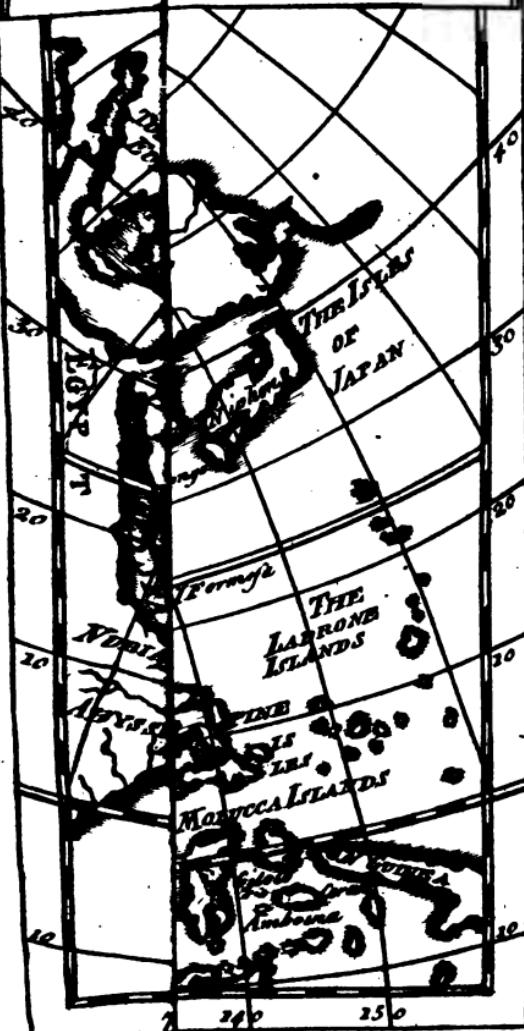
Though the *Dutch* have confined the Culture of Cloves to the Island *Amboyna*, of which they are Masters; though they have the finest Plantations of all the other Kinds of Spices; though they have had the Skill to exclude other Nations from the Commerce of the Silver and Copper of *Japan*, of the Cinnamon and precious Stones of *Ceylon*, and without Dispute make the greatest Figure in all the East; yet the *English* have by Degrees had some very advantageous Retreats at *Madras* in *Coromandel*, at *Surat*, *Bombay*, and *Amadabad* in *India*, at *Banderaboffi*, a Seaport where all maritime Commerce is carried on, and which they assisted the *Sophy* in forming on the Ruins of the Establishment of the *Portuguese* at *Ormus*.

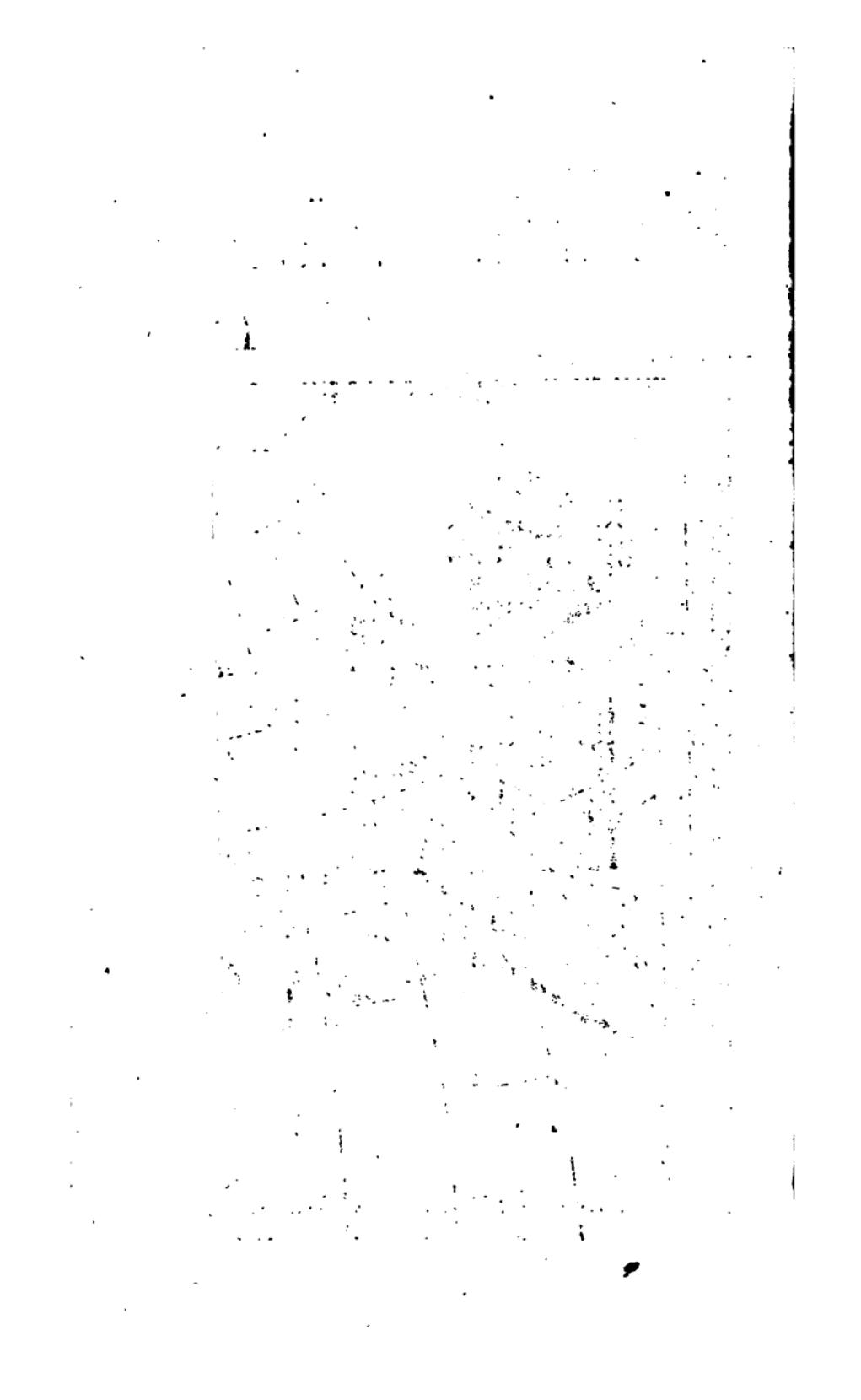
The Commerce of France in the nothing but Wars, or intriguing in foreign Courts, the French Merchants always saw their Wishes and Efforts towards sharing the Treasures of the East.

frustrated. But now that the Vanity of Conquests has made Room for the Love of simple Justice, and the Support of Commerce is looked upon as the Safety of the State; - the French Company in Return looks upon itself as the first Object of the Attention and Concern of the Public. We are now more agreeably taken up with all its Transactions, than we formerly were with

* In the Year 1648.

THE OPEANS





with the Motions of our Armies: In consequence of which, some new Successes chears our Hearts every Year. That Company maintains its Credit, by the new Establishment it secures to itself in the East, and by the Improvement of the most ancient, without meddling with the Commerce of the Sea-ports in the *Levant*, or with that of *Canada*, *Mississippi*, and the Islands; the Profits of which are left to private Merchants. They fetch our best Pepper from *Mabé in Malabar*, near *Calicut*. The City of *Pondicherry*, the Property of which belongs to them in *Coromandel*, and which becomes one of the most flourishing in all the *Indies*, as well as their Settlements of *Masulipatan*, and several other Houses of Traffic on the same Coast, enables them in due Time to fetch from all the *Indian* Kingdoms Rice, Cardamum the Sauce for it, Steel, Cotton-wool, and Cotton spun incomparably finer than that made by our *European* Women, Muslins, Calicoes painted and printed with Moulds, or still more nicely worked by the Pencil, the Diamonds of *Visapour* and *Golconda*, and many other Commodities, which they trade in from one Part of the *Indies* to the other. By this Means they make amends for the unavoidable Disadvantage they lie under, of making the first Purchase with ready Money; because the Inhabitants of the Peninsula of *Indus* make little Use of our Wools and *European* Commodities. The Post of *Cibander Nagor*, which the Company possesses near *Ongly*, at the Mouth of the River *Ganges*, opens them the Door into the whole Country of the *Mogul*, whence they fetch their Velvets, Brocades, fine Camblets, the best Indigo, Saltpetre, Borax, Lac, Musk, and Rhubarb, which is brought thither from *Boutan* and *Tartary*. The French Company, by Means of the House which they hold at *Mergui* on the Western Coast of the Peninsula of *Indus*, on the other Side the *Ganges*, may also trade in Rabies, and all the coloured precious Stones of *Pegu* and *Ava*, as well as in Areque and Betel, two Drugs which the *Indians* are perpetually chewing; in Tin, Timber, Tortoise-shells, and many other Commodities which are in Vogue at *Saiajutaia*, the Capital of the Kingdom of *Siam*, on the River *Menam*. They are no less attentive to the Exchange (oftentimes very beneficial) which is made of Silver for Gold in the Kingdom of *Chine*. Their two Islands,

Islands, called *Maurice* and *Bourbon*, at the East of *Madagascar*, are the commodious Staple of whatsoever they send from *Europe*, and bring back from the East.

In this summary Account of the Progress of Commerce, which now takes in almost the whole inhabited World; you see the inestimable Advantages which the Knowledge of the Load-stone procured us.

The Progress of Physics. But if the Science of Physics has been of Physics. of this Service to Commerce, Commerce

in Return has totally changed the Face of Physics and of all Sciences. By bringing into each Country the Productions of all the rest, it has gradually led Men into a right Way of thinking. From Metaphysics, which filled the World with unprofitable Disputes, it brings them back to the Examination of what may be seen and done. While the Philosophers of the Schools were spending their Lungs in public about trifling Questions, or privately racking their Brains, in dividing their own Ideas into Sections and Paragraphs, without ever minding whether those Ideas were agreeable to Nature and the World, which they carefully avoided ever looking into, there sprung up a new Kind of learned and true Philosophers, whose Knowledge was grounded on Experience, and relative to our Wants. You perhaps expect here to have the History of the Principles of *Descartes*, or of the Theodicy of *Leibnitz*: But these will find a Place in the History of systematical Physics. The first Naturalists, who have been instructed by Commerce, and whose Learning was so useful to us, are our Navigators and Druggists. Let us now see, what we are beholden to them for.

Navigators, whose Numbers increased every Day, of Necessity became Mathematicians and Astronomers; and by Consequence Astronomers and Mathematicians every where sprung, who chiefly wrought for the Assistance of Navigation. About the End of the fifteenth Century, *Purbach*, a Professor of Philosophy at *Vienna* in *Austria*, having, by the Advice of Cardinal *Bessarion*, learned the *Greek* Tongue, made himself capable of translating from the original Text the great Construction of *Claudius Ptolemy*. His Disciple *George Muller*, surnamed *Royaumont*, composed the *Ephemerides*. *Stoeßler*, another *German*, gave very good Directions for constructing

constructing the Astrolabe. In France, about the Beginning of the sixteenth Century, Oronce Fine, the royal Reader, encouraged by the Gratifications of Francis the First, the Restorer of Letters, and assisted by the Accounts which then began to be sent from the Indies and the new World, made geographical Maps; constructed more particular Globes; invented new Instruments to carry on the Work both of Sailors and Persons who made Observations, and instructed a Mokitude of Mathematicians. He applied Astronomy to Clock-making, and was the first who attempted to produce an astronomical Pendulum *, which in every Thing moved according to the Notions of Ptolemy.

It must be confessed, that the geographical Maps, which we have of those Times, are extremely defective. They sometimes have *America* divided into two Parts towards the Middle; though the Northern *America* be joined with the Southern by the Isthmus of *Panama*. They most commonly shew a Passage towards the North into the *South Sea*, though the *English*, *Danes*, and *French* Pilots have always sought for it in vain: Just as the *Dutch* have to no Purpose looked for a Passage round the North of *Tartary*, to get into the East. So that the ill Success of all these Attempts makes us presume, or even affirm, that *Tartary* is joined to *America*, and that we must no longer think of going to the *Indies* or *China*, by the North of *Tartary*, or the North of *America*. We very often find in these antient Maps, the *Southern America* lengthened out to the Meridional Pole; though *Magellan* and *Le Maire* have, by turning round it through the *Magellanic Straights*, and behind the *Island of Fire*, informed us, that *America* is separated from the *Terra Australis*. Notwithstanding these Defects, and many others, if all the old Treatises of the Philosophy of the Schools (the Heap of which would indeed be very large) were put on one Side, and the Maps of *Peter Appian*, or of *Oronce Fine*, unfinished as they were, on the other; I should set no other Difference on their Value, than that which is between rough Diamonds, which in Time will be fashioned, and Dreams which deserve nothing but Oblivion.

When the several Parts of the Mathematics had once enchanted all Minds, by the Exactness of their Demonstrations, and the vast Usefulness of their Productions; the Philosophy of the Schools was looked upon as a temporary Exercise, which might, they said, be made use of to sharpen the Wits of Youth: But they relished, and consequently applied themselves to useful Physics, which filled Mankind, not indeed with empty Words, but with real Things. The Study of Geography and the Globes, that of the Winds, the Tides, and the Moon, of the Heavens, and all their Motions, of Compasses, and all their Uses, of Arithmetic and Mechanics, came every where into Favour, and met with sure Rewards in the nice Taste of Princes, and the Gratitude of the Nations which were inriched by that Sort of Physics.

Next to Travellers, who have awakened Curiosity amongst us, and made us sensible of the Necessity of Mathematics, those, who have promoted the Advancement of experimental Learning most, are our Druggists; who, by setting in Order the foreign Productions, have as it were gathered before our Eyes the Particularities of the whole inhabited World. These rich Collections of the Works of Nature, opened new Treasures to Pharmacy, to Divers, Goldsmiths, Painters, Chemists, and to Arts and Sciences in general. All found therein new Trials to make, new Hints of Truth, and sure and solid Informations.

Natural History was then undeceived, with regard to the Origin and Virtues falsely attributed to several Productions of Nature, and daily discovered the Usefulness of ten thousand others which she knew not: Nay, Anatomy itself, which seems not to stand in any need of the Assistance of Foreigners, found in the Dissection of Animals unknown to Europe, the Confirmation of what was as yet only suspected, and the ascertaining of what had hitherto escaped our Researches. They at last grew weary of unfruitful Disputes, and Notions daily contradicted by the Inspection of Nature. By Degrees, we are come to that wise Method of investigating Truth, not by Arguments, or the Authority of any Philosopher, but by Experience, and by Means of our own Hands and Eyes. The Study of the Productions of Nature, or of the Uses to which they may

may be applied, (a Work formerly looked upon as but Loss of Time, or an Employment fit only for low Mechanics) is now thought the only valuable Philosophy. A Prince or a Lord, among us as well as among our Neighbours, would be pitied, should he talk of metaphysical Degrees: But he thinks it an Honour to have a Virtuoso's Cabinet; and the more he is acquainted with every minute Individual of it, the more he shews himself informed of the true Concerns and Works of that Society, to the governing of which he was appointed by Providence.

The Care which good Masters now-a-days take to clear Philosophy from frivolous Questions, to treat there on at large Geometry and Mechanics, and to make the whole refer to Experience and the Necessaries of Life, is a just Motive to applaud the Custom of trusting them for two Years together with such of our Youth as are designed to fill the Posts in Church and State. But their Labour might be rendered incomparably more useful, if, in order to improve the Masters themselves, their School (at least in large Cities) had in it a Virtuoso's Collections, a Garden filled with all the common Plants, and a regular Course of physical Experiments.

One might copy in little the Order of the magnificent Cabinet of Rarities, both artificial and natural of Mr. Bonier de la Moisson *. We find the Model of a small Garden of five or six hundred useful Plants, in Mr. De la Serre's † Garden, where the Tickets which are placed near each of these Plants, are in lieu of Masters and Informations. A Model of an excellent Course of Experiments may be taken from that of the Abbe Notter ‡, where every body may, without any earnest Application of Mind, and in less than twenty Conferences, be informed of the most important Points of Natural Philosophy.

The Prince and the Magistrate, the Preacher and the Merchant, and all such as are appointed to direct the Interests, or form the Minds of Men, might, in these agreeable Demonstrations, learn how to talk, and knowingly

N 5

deliver

* Rue St. Dominique.

† Fauxbourg St. Jaques, proche de l'église de St. Jaques du Haupeau.

‡ Deau-Contis.

deliver their Opinion of whatever is useful. They might find in a Cabinet of Natural History, of Mechanics and experimental Physics, the Patterns of whatever Men can collect, exchange, manufacture, or work; as also of all the Errors which may be made in them: And, in short, the whole Matter of Commerce and Industry. An Establishment like this would have the uncommon Advantage of fitting all Conditions and Geniuses, of attracting all Men, and of tiring none, of forming and refining our Taste, of maintaining Curiosity and Correspondencies every where, of keeping many Eyes opered on the Particularities of every Country, of adorning the Mind with a Knowledge every where manly and becoming, of even affording the Topics of the most entertaining Conversations, and (what is indeed an inestimable Point) of affording every body an infallible Means of busying himself usefully. A Philosophy like this would, in some Sense, be *the Art of living happy*.

THE TELESCOPE.

DIALOGUE VI.

THE particular Account of the Experiments of modern Philosophy has no Bounds ; and yet we cannot avoid prescribing Limits to ourselves. I then shall think myself to have gone through the whole History, and yet have made it short, if I confine myself to such Experiments as are most fruitful in great Effects, and chiefly to the three Inventions of the seventeenth Century, that cast the greatest Light on all Parts of natural Knowledge. You see, Sir, that I mean here the Telescope, the Air-pump, and the Microscope. These three Instruments are in Astronomy and universal Physics, what the Furnace is in Metallurgy, the Lever in Mechanics, and the Compasses in Geometry. They every Day make us discover, either in the Order of the Heavens, or in the Texture of Bodies, or the Relations the several Parts of Nature have with our Wants, a Number of Truths which were not known, or evident Proofs of what we had but an uncertain Glimpse of. These three Instruments are become Guides to all Observers : And acquainting one's self with the Discoveries, for which we are beholden to the Telescope, the Air-pump, and the Microscope, is learning the noblest Parts of both practical and speculative Physics.

The Invention
of the Tele-
scope.

A Sort of Chance gave Birth to the Invention of the Spying-glass or Telescope. The Children of a certain Spectacle-maker of Middlebourg, in the Island of Zealand, playing in their Father's Shop, made him observe, they say, that when they held between their Fingers two Spectacle-glasses, and put them one before another, at some Distance, they saw the Weather-cock of their Church much bigger than ordinary, and as if it were very near them, but in an inverted Situation. The Father, amazed at this Singularity, bethought himself of adjusting two Glasses on a Board, supporting them in two Brass Circles, which might be removed or set closer *ad libitum*: By this Means they could see better and farther. Many Virtuosoes flocked to the Spectacle-maker: But this Invention remained a while unfinished, and of no Use. Some other Workmen of the same City, one called *Zacharie Jansen*, and the other *James Metius*, in Emulation of each other, made use of that Discovery, and, by the new Form they gave it, made all the Honour of it their own. One of them, considering the Effects of Light, placed the Glasses in a Tube blackened within. By this Means, he diverted and absorbed an infinite Number of Rays, which by reflecting from all Sorts of Objects, or from the Sides of the Pipe, and by not reaching the Point of Re-union, but falling on one Side, confused and dimmed the principal Image. The other, still more cautious, placed the same Glasses within Pipes jointed, and sliding one in another, both to vary the Prospects by lengthening the Instrument at one's Will, according to the Wants of the Observer, and to render the Machine portable and commodious, by the Diminution of its Length, whenever it should be either removed from one Place to another, or laid by and no longer made use of. There are some Contests among the Learned, about the Share which the two Artificers above-mentioned had in the Invention of the Telescope. To avoid Quotations and tiresome Disputes, I shall only inform you, that several Men, by a Variety of Experiments, contributed to the Perfection of that Instrument; and that it is to the Dutch the Public is indebted for so noble a Present. When it first appeared, it had no other Name but that of *Lunette d'Hollande*.

It was soon noised abroad ; and *Galileo, Astronomer to the Grand Duke of Tuscany*, having heard of it ; they say, that without having had as yet any Model before his Eyes, and on the bare Idea which the Recital only gave him of them, he framed several large Glasses, and adapted them to some long Organ-pipes, with which he perceived some Spots about the Sun. He saw that Star moving on its Axis in near twenty-six Days : He discovered the four Moons of *Jupiter*, and called them the Stars of *Medicis*. He had a Glimpse of two Ears or Handles on both Sides of *Saturn*, which afterwards proved to be a large luminous Ring, wherewith this Planet is compassed : In short, he saw a new Heaven, and a Sun quite different from that hitherto seen. He soon gave the Public *some News of those starry Regions*, which his Glass put within his Reach. Here I use the very Title of the agreeable Account he published of his Discoveries.

This was soon heard of every where. It is universally known, that the Senators of *Venice*, who were most eminent both for their Learning and their Love of the public Good, invited *Galileo* to come, and in their Presence to make a Trial of his new Instruments. He complied with their Desires, and in a fine Night, neither cold nor cloudy, he shewed them with his Telescope the new Phænomena, which were now every where talked of, and which the Learned refused to admit, because they overthrew all their Notions. That Night was fatal to the System of the Schools ; and the perfect Conformity which *Galileo* caused the *Venetian* Nobility to remark, between the new Observations and the System of *Copernicus*, began to give Credit to that System. Never Conference was so illustrious, or of greater Concern. But nothing hinders us from assisting thereat, and hearing *Galileo* himself speak. Let us transport ourselves in Imagination to the Tower of *St. Mark*. The Master we are going to hear, the Audience, and the Novelty of the Invention, all, in short, will concur to make us relish this Astronomical Lecture.

Let us suppose the Night appointed for the Rendezvous is come : The Stars beginning to sparkle on all Sides : Their

• *Nuncius Sidereus.*

Their Number and Splendor increasing on the Diminution of the Twilight: The Tubes mounted and pointed: The Lords upon the Tower: Most of them already have satisfied, one after another, their first Curiosity, by directing the Glasses towards several Points of the Heaven. But the Planet *Venus*, seen after Sun-set in the greatest Distance it can be in with regard to that Star, being the finest Star which then strikes their Eyes; all turn their Attention towards it; and their Surprize is extreme, to find in the Glass the Figure of *Venus* obscured one Half, and horned from Side to Side; instead of appearing round in the Glass, as it does in the Eye. How! Is then *Venus* to be eclipsed? But how can that be, when the Earth is not between her and the Sun? Does such a Thing ever happen? Is there any other Body besides the Earth, that can cast its Shadow on that Planet? Is *Venus* ever eclipsed? Or has *Venus* its various Phases as well as the Moon? Has she also her Crescent and her Full? To all these Questions, and a great many others, incessantly multiplied, here is *Galileo's Answer*.

Gentlemen,

It is from the Observation of this Phænomenon, that the Decision of the great Question, which divides Astronomers, does now depend. In order to enable you to judge of it, I am first to lay before you their Thoughts about the Economy of the Heavens. We shall afterwards come to the Use that may be made either against or in Favour of their Sentiments, of the Phases which we just now observed, and which were not known before in the Planet *Venus*. I cannot entertain the Company with a nobler and more agreeable Topic, till the Rising of the other Planets; in which I am to observe to you Singularities no less strange than is the Crescent of *Venus*.

The System of *Eudoxus*, *Aristotle*, *Hipparchus*, and all the Greeks, who began to search into the *Ptolemy*.

Order of the Heavens; *Ptolemy*, who in the second Century improved Astronomy; after him the *Arabians*; next to these *Alphonso* King of *Castile*; *Sacrobosco* Professor at *Paris*; *Parback* in *Austria*, in the fifteenth Century, and his Disciple *Royaumont* in the Sixteenth; in short, almost all the Astronomers have made the Earth the unmoveable

moveable Centre of the Universe. They suppose that the other Planets revolve round the Earth in so many different Heavens, nearly concentric, and raised one above another, *viz.* First, the *Moon*; then *Mercury*; and then in Order, *Venus*, the *Sun*, *Mars*, *Jupiter*, *Saturn*, and at last the fixed Stars. It was not an easy Matter for them to conciliate the daily Motion which carries the Stars round the Poles of the World from East to West, with another peculiar and very slow Motion which carries them away round the Poles of the Ecliptic, and from West to East in the Time of 25,000 Years; and at the same Time with a third Motion, which hurries them away in a Year, and from East to West, round the Poles of the Ecliptic. They were no less at a Loss, how to reconcile the annual, and the daily Motion of the Sun in quite contrary Ways. A new Difficulty joined to these, about the particular Course of each individual Planet. They heaped up one Mobile upon another, one of which went one Way, and the other another. After the first Mobiles, they placed some very large Heavens of solid Crystal, which by rolling one over another, and by a mutual and violent Clashing, did communicate to each other the universal Motion received from the *Primum Mobile*; while they by a contrary Motion resisted this general Impression, and by Degrees carried away, each after its own Manner, the Planet for the Service of which it was designed. These Heavens were solid; otherwise the upper ones could have had no Influence on the inferior to make them daily move; and they were of the finest Crystal, because the Light of the Stars could not otherwise have penetrated the Thickness of these Arches applied one over another, nor have reached our Eyes. Many Astronomers were so moderate as to be contented with seven or eight different Spheres; while others wrapt no less than seventy of them one in another. They no sooner discovered some new Motion or Effect as yet unknown, but they immediately patched up a new Sphere. But among the rest, nothing is more arbitrary than their Way of explaining each after his own Method, the Singularities of the Course of the Planets. It is observed of most of them, that in a certain Time they advanced directly according to the Order of the Signs, that is, from West to East: That they afterwards are for a while still in the same Point of the Heaven, and finally, that they seem

seem retrograde, and to repass from East to West, through many of the Points which they had before run over. To account for this, they all of them make the Planet roll from West to East on the Border of a little Sphere, which they call *Epicycle*, while the Centre of that Sphere rolls the same Way on the Arch of its *Deferent*, that is, of the great Heaven which is peculiar to it. Whence it happens, according to them, that when the Planet ascends the Top of its *Epicycle*, we see it go directly, and according to the Motion peculiar to its own Heaven. When afterwards it descends into the Quadrature, or Under-side of the *Epicycle*, it seems stationary: Because as much as its Heaven carries it away, according to the Succession of the Signs, so much it deviates therefrom, by advancing in the Under-part of its *Epicycle*, contrary to the Succession of the Signs. Then, they say, it must appear retrograde, when advancing in the inferior Part of its *Epicycle* from East to West, and quicker than its Heaven advances from West to East, it is seen going back, till it again appears motionless and stationary; when again ascending the Side of its *Epicycle*, it advances one Way no more than its Heaven advances the contrary. It is no easy Task to tell you how their *Epicycles* could move through these thick Crusts of Crystal: They however found Means to extricate themselves; as they always had Recourse to geometrical Lines, which never found any Obstacle to their Passage on Paper; the whole passed for true Physics. They foretold Eclipses, and the Returns of the several Aspects. Who, after all this, could have doubted of their having the Key of the Structure of the Heavens? It is true, in Order to make all those Pieces move with as little Inconsistency as possible, especially when they were to give their Spheres different Centres, they were forced to delineate some certain Furrows, or to notch on the Arches some Grooves, in which they jointed, and made the Tenuons and Mortises of their *Epicycles* to slide. All this celestial Joiner's Work, to which others still added several Pieces, fit therein to produce Balancings, or perpetual goings backward and forward, did so much displease the King of *Castile* (who, for want of something better, took the whole for good Truth) that he one Day said, in the Perplexity which this Multiplicity of Orbs and Orbits gave him, that if God had called him into his Council, the Machine

chine of the World would have been much less complex. This profane Jeſt is neither for the Honour of the royal Astronomer, or that of the Hypothesis which gave Birth to his Majesty's Impatience.

Astronomers, notwithstanding the Liberty they took to multiply Machines according to their Wants, yet never contrived any Thing that could account for the Appearances of the Motions of *Mercury* and *Venus*. The brilliant Planet yonder, according to Astronomers, turns round the Earth as round its Centre: But, according to Truth, it turns round the Sun. No Astronomer ever saw the Earth between *Venus* and the Sun; and I can give you Proofs of my having often seen *Venus* beyond the Sun, which overthrows their Hypothesis, and gives me an Occasion of proposing another, more agreeable to the Experiments which the Telescope procures us. Were it true, that *Venus* turns round the Earth, it should first be (as really it is) seen to pass between the Sun and the Earth, that is, in Conjunction. The Earth should also be sometimes seen between the Sun and *Venus*, which would then be in Opposition, or 180 Degrees from the Sun; which never happens, since *Venus* is never seen more than 48 Degrees distant from the Sun. She then begins to draw near him again, and at last is lost in his Rays. But though they should, by their Epicycles and Machines, be able to account for the Appearance, according to which *Venus* never goes more than 48 Degrees from the Sun, as we now see it; there is still an Observation, which must make us for ever dislike the Order which *Ptolemy* thought he perceived in the Heavens:

The Planet *Venus*, which you just saw in the Telescope under the Form of a Crescent, or rather as the Moon when near a Quarter-old, is seen thus horned, merely because it shews us a Part of its enlightened Half: It begins to draw near its Conjunction. In a few Weeks you will see that Crescent grow less, and disappear at last, when the Planet, coming down between the Sun and the Earth, shall turn its whole dark Half towards the Earth. By Degrees she will disengage herself from the Rays of the Sun; and being more Westerly than he, we shall no longer see her at Night, but in the Morning. She will be seen sooner than the Sun; since the Sun being then more towards the East, will not appear above the Horizon till after her. But the more you shall

shall then observe her Progress in the Morning, the larger and rounder you will see her every Day. The Telescope will make you see her almost wholly, or like the Moon near its Full: Which can proceed from no other Cause, but her shewing us at that Time almost her whole inlightened Half. The fuller she becomes, the more she is then seen to approach the Sun. You are sensible, that were she then between the Sun and us, she could not be seen at all; since her whole inlightened Half would then be turned towards the Sun. If then she is seen almost intire, and drawing near the Sun, it is because she is beyond the Sun; in which Case we must needs see her on the inlightened Side: She then turns round the Sun, not round the Earth; and if so, we must of Course find the Proof of it in the Decrease of her Brightness, which must be proportioned to her Distance. Now that she is, with regard to us, as much disengaged from the Rays of the Sun as she possibly can be, and drawing near us, her Splendor must be very great. Of this you are now convinced, by the bare Testimony of your Eyes. On the contrary, when three Months hence she shall be near her Full again, though seen in Front, she must be much less brilliant, because we then shall see her only in the Neighbourhood of the Sun, and with regard to the Earth, more remote by the whole Diameter of her own Orbit. Of this I was also informed by the Telescope; and daily Experience may convince you of it. Therefore *Mercury* and *Venus* (for it is with the one as it is with the other) do not turn round the Earth. These two Planets, and very likely all the rest, have the Sun for their Centre. *Ptolemy's Hypothesis* is then demolished; and without coming to Confutation of whatever is therein advanced, it is self-evident, that astronomical Observations clash with it, and therefore it must be for ever rejected.

It is not enough for me to have demonstrated the Falsehood of that System: I must yet replace it by another Hypothesis less complex, and more agreeable to Appearances. But I beg of you, Gentlemen, to remember, that the new Order I now offer you, though more satisfactory in all Respects, yet is still but a bare Supposition. The Heaven may be very different from what I take it to be. I give you my Thoughts only as such, and would willingly, if possible, be at Variance with no body.

The

The Ground of that Hypothesis is not mine. I am satisfied, Gentlemen, with the Pleasure (indeed not inconsiderable) of communicating to you the Proofs which make it acceptable, by shewing you in the Heaven with this new Instrument, what the Eye, without that Help, could not distinguish there before, and what would have given to the Author of that Hypothesis much greater Confidence.

It consists in saying, that the Heaven and the Stars, with regard to us, are perfectly at Rest, and that the Motions by us ascribed to them, proceed only from the Earth, which moves on its Axis, and is with the other Planets carried away round the Sun as their common Centre. This Idea is very far from being new, but it met with too great a Resistance from universal Prejudice, to be able to gain any Credit. The *Pythagoreans*, above 500 Years before Christ, taught it in a very mysterious Manner, as they did all their other Opinions. Afterwards *Philolaus*, *Aristarchus*, and above all, *Cleantus of Samos*, gave Offence to many, by openly teaching, "That the Heaven was at Rest, and that it was the Earth which was carried round the Sun, according to the Line of the Ecliptic, daily turning on its own Axis". This Opinion was almost forgot till the last Century, when Cardinal *Cusa* revived it. But neither he, or any of those who maintained it before him, had observed enough to have a Right to overthrow the old Hypothesis, which had been of so long standing, and was thought to be founded on the Testimony of the Eyes.

At last *Copernicus*, born in the Year 1472, at *Thorn* a City of *Poland*, and a Canon of the Church of *Warmie*, ruminated on this Opinion again, cleared it perfectly, and by assiduous Observations found it wholly agreeable to the State of the Heavens; and having given his Books *Of the Revolutions*, after thirty Years Labour, he surprized all the understanding and attentive Part of Mankind, by making them perceive a most wonderful Exactness and Simplicity, in an Opinion hitherto rejected as absurd. The Sum and Substance, which I shall here give you of it, will, I hope, neither be thought tedious or unnecessary.

It

* Μένειν τὸν ἀρανὸν ὑπολιθίουν. Ἐξαλτεοθεῖ δὲ κατὰ λόξη κύκλου τὸν γῆν, ἥμα τὸν τερπὶ τὸν αὐτὸς ἀξονα διεργάτεν. Plutarch. de facie in Orbe Lunæ.

The System of *Copernicus*. It is a constant Rule of Nature, that we see those Objects turn or move whose Images change their Places in our Eyes, or pass from one Point of the Eye to the other, without moving the Eye or the Head. It is another Rule of Nature, perfectly agreeably to the first, that Objects appear to us fixed, when their Images remain painted in our Eyes on the same Points of the Retina, without varying. Thence it happens, that sitting in a Boat, all Parts of which are always in the same Situation, both with Regard to themselves, and with Regard to us, and the Image of which consequently does not change its Place in our Eye, we then see that Boat as unmoved, though it be continually in Motion. On the contrary, the Images of the Tower of St. Mark, of the Steeples of *Venice*, and of the Trees that surround the Terraces, change their Places in our Eyes, and pass from one Point to another, according as the Gondola brings us near those Objects, makes us pass by, or carries us from them. By a necessary Consequence of this Motion of the Images, it always happens, that we perceive all the Objects which respectively correspond to them, as though in Motion. We see the Town, the Steeples, and the Trees on the Water-side coming towards and passing before, or afterwards going from us; while it is ourselves who leave the Port.

Proverbimur porta; terræque urbesque recedunt.

Let us now apply this Observation to the System of Nature. If instead of making the Sun, the Stars, and the immense Number of the celestial Bodies, to turn round and be for the Service of the Earth, which is but a Point in Comparison, it had been the Pleasure of the Author of all Things, to make the Earth and other Planets turn round the Sun for several Months together, and each of them turn in a few Hours on its own Axis; we then should see Things go just as we now do. The Expence would be but very little, and yet the Effects be equally magnificent. The Stars and the Sun, though constantly fixed in one Place, without ever leaving of it, would appear to us to ascend, to go down, and then disappear. The Earth, though constantly advancing in a great Circle round the Sun, and making every four and twenty Hours a whole Revolution on itself, would seem to

as perfectly still. It is plain that the Earth would appear unmove, since all the Points which we see on the Earth being always in the same Order, both among themselves and with Regard to us, the Images of them painted in our Eyes would never change their Place at any Time. On the contrary, the Sun, the Planets, and the Stars, would seem to us perpetually coming up or going down, according as their Images should come and place themselves in the lower or higher Part of our Eye. The Planets, especially, having a peculiar Course of their own, while our Earth has also its proper Motion, would seem to us to have the greatest Variety of Motions, though they had indeed but one, and that very uniform. Let us begin with the clearing of this Point, the most difficult of all; after which, the daily and annual Motion will no longer be perplexing to us.

Nothing in the World can be more intricate than the Course of the Planets in *Ptolemy's* Hypothesis: Nothing, on the contrary, is more simple than all the Directions, Stations, and Retrogradations of the Planets, in *Copernicus's* System. Give me Leave, Gentlemen, in order to make you sensible of the important Doctrine of the Polish Astronomer, on the apparent Irregularities of the Planets, here to chuse three or four Objects on the Platform of this Tower, and at Pleasure to make them move round an unmoveable Point, which I will call the Sun. The illustrious Lord *Sagredo**, quietly sitting in the Middle of this Place, will be so good to stand us in Lieu of that Star. He shall, if he pleases, have both the Function and the Name of it, since he conveys Joy and Light wherever he goes. Let us take the Footman *Veronese*, which I find here with his Flambeau, to represent the Planet *Venus*. I shall indifferently call him *Venus* or *Veronese*. As for me, I shall be the Earth, and in whatever I shall say of the Motions of our Globe, *Galileo* or the Earth shall be but one and the same Thing. Let *Veronese* turn in fix or seven Minutes round the Lord *Sagredo* at a reasonable Distance: I shall at a farther Distance make the same Circuit in twelve Minutes: So that he will double or complete almost two Revolutions, while I shall make but one. *Veronese*, as he goes, shall always turn himself towards the Sun,

* That *Venetian* Lord had a very tender Love for *Galileo*, and he is one of the Persons whom the great Astronomer introduces speaking in his Dialogues.

Sun, in order to imitate with his Face the enlightened Half of that Planet, and with the hinder Part of his Head that Half of *Venus* which remains darkened. Here is now the Result of the Concourse of our two different Courses.

Now that *Veronèse* is almost between the Sun and me, I see the Sun; but *Veronèse*'s Face, which is turned towards the Sun, is wholly hidden from me. The Planet is then invisible as it draws near to its Conjunction. *Veronèse* goes faster than me: He passes under the Sun: He goes somewhat from me on the Right, and I begin to see his Face in profile: This is the Crescent of *Venus*. As he advances, and is ready to get behind the Sun, still looking at him, he turns his full Face towards me: I then see *Venus* at full, or, nearly so. I see her so, only because she turns, not indeed round me, but round the Sun. When *Veronèse* (still going before me, since he goes twice as fast) shall have disappeared a while, being hid behind the Sun. I shall soon see him appear again in full to the Left of that Star. As he shall come down towards me, still looking on the Sun, I shall see his Side-face, till he wholly disappears again, by placing himself directly between the Sun and me. In which Situation he offers to my View only the hinder Part of his Head. You then have here the Diversity of the Appearances of *Venus*, such as the Telescope discovers them to you, very well deduced from the Circuit of *Venus* round the Sun; and the Necessity of that Circuit demonstrated by Phases which suppose its Reality. For the Earth being never between *Venus* and the Sun; if the enlightened Half of that Planet may be seen almost full, that can only be when the Earth is on this Side the Sun, and when *Venus* proceeding on the other Side of that Star, is ready to pass behind it.

In the second Place, I beg of the Company to extend their Sight along the Parapet which crowns the Tower, and there to remark from Right to Left a Series of Points; for Instance, the Stones which I have chalked and marked A, B, C, D, E, F, and as many more as the Company shall think fit. - When *Veronèse* makes Half of his Course from Right to Left on the other Side the Sun, and I make the quarter Part of mine on this; I see his Flambeau successively pass from the Right to the Left under the Stones A, B, C, D, E, F. But when afterwards, continuing his Circuit,

he

he comes down, and places himself between the Sun and me, I see him pass from the Left to the Right, over-against the Points F, E, D, C, B, A. And though he proceeds in an uniform Course, I see him running over the same Points of the Parapet, in a Way quite contrary to the foregoing.

If then I see in the Heaven the Planet *Venus*, or any other, pass under the Stars A, B, C, D, and afterwards see it turn back and pass again by D, C, B, A; it is not because it keeps not a regular Course, as that of *Veronese* was, but that Variety of Appearances proceeds from its turning round the Sun, and from the Earth's doing the same, but *Venus* faster and the Earth slower; whence follows that Diversity of Aspects, and an Appearance of Irregularity.

Now let us make use of a Figure where I have delineated all those Things at large and in a regular Manner, in order to put something of Exactness in the Order of the celestial Appearances, which I have as yet only sketched out. The understanding of this Figure, though it be geometrical, yet supposes no Knowledge of Geometry. Those who govern Nations, have little Time to draw Lines, or to work with Compasses. It is our Busines to render Truth palpable to them, without perplexing them with enigmatic Demonstrations. I shall be contented with only distributing to the Company such Figures as will plainly express the Progressions, Stations, and Retrogradations of the Planets *. They may afterwards examine them at Leisure with the Explanation annexed, and there remark on one Hand the amazing Fruitfulness of the *Copernican* System, which accounts for every Thing with one and the same Principle, and on the other, its perfect Agreement with the Phænomena which *Copernicus*, for Want of the Assistance of the Telescope, never knew.

In *Copernicus*'s Time, his Adversaries thought they had intirely confuted him, by telling him, that if the Heaven was ordered as he pretended, *Venus* and *Mercury* must vary their Phases as the Moon did; that *Mars* in Opposition, that is, drawing near the Earth placed between him and the Sun, should appear much bigger, and that that Planet should, on the contrary, sensibly diminish, when it should

get

* See the Explanation at the End of this Volume.

get behind the Sun, and recede from us by the whole Diameter of the terrestrial Orbit. *Capernicus* agreed with them, that these Consequences were justly drawn; and he attributed the Cause of the Inequality of the Appearances to the Structure of our Eyes, and to those radiating Crowns, which hinder us from judging either of the Bigness, or of the exact Form of Stars.

How great would have been the Transports of that great Man, had he been able, like ourselves, to perceive the Full and the Crescent of *Venus*, of which he found the Necessity, without being able to convince others of the same: He would immediately and for ever have ruined the System of the Schools, which makes *Mars* to turn round the Earth at an uniform Distance; had he but seen that Planet such as our Telescopes shew it us, *viz.* sometimes receding from the Earth by a prodigious Distance, and diminishing both in Shape and Splendor, as it draws near its Conjunction on the other Side the Sun; then gradually appearing fifty or sixty Times bigger, as it arrives towards its Opposition, and again draws very near the Earth placed between it and the Sun.

He would have been still more pleased, to have discovered the four small Moons which turn round *Jupiter*; since they shew, that our Earth in all Respects resembles any other Planet; and that as *Jupiter* has four Planets of the secondary Order, inseparably bound to its Service, that is, four small Moons designed to light it during the Night of its obscure Half, so has the Earth a subordinate Planet, which performs the same Functions for her Sake. Nay, who knows but Men, with Instruments better still than mine, will, one Day or other, discover that *Saturn* in its extreme Remoteness from the Sun, was still better provided with the Help of nightly Flambeau? I have already begun to observe there a Sort of double Handle, which reflects a very great Light upon it *. In short, whatever I daily perceive

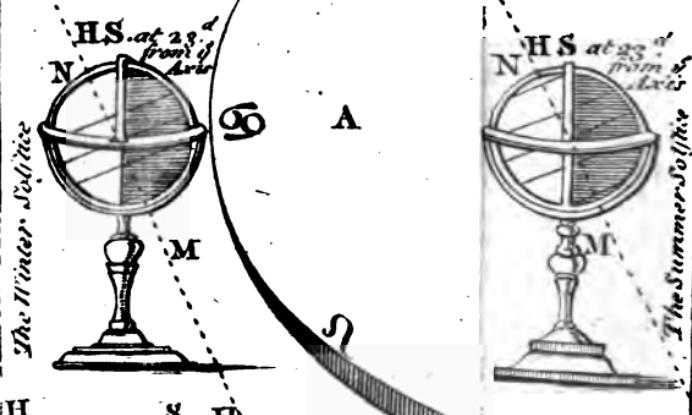
* These Handles, which *Galileo* had seen near *Saturn*, were the Extremities of the luminous Ring wherewith we see that Planet wholly incompassed, when it is turned another Way.

Mr. *Caffini* has exactly observed that Ring, and discovered four small Moons by it.

Mr. *Buygens* saw the fifth.



The

Solar Horizon
rees from the

The

A piece of Part board cut Semicircular
with two Supports CC, to make it stand
at pleasure upon the Horizontal Circle,
and thereby to fix the Progress of the
Solar Horizon, which varies when ever
the Terrestrial Globe is displaced.

perceive in the Heavens, becomes a new Proof of the Solidity and Exactness of that System, which places the Sun in the Centre of the Planetary World; and makes the terrestrial Globe turn round him like the other five Planets.

After this Illustration both on the Order and Course of Planets, the rest of the Hypothesis, which accounts for the diurnal Motion of the whole Heaven, and for the Inequality of Days and Seasons, becomes an Amusement rather than a Study.

I have caused here an oval Table (A) * to be placed, whose Plane may be looked upon as making a Part of the Plane of the Ecliptic. We may lengthen this Plane out in Imagination, and make it reach to the Middle of the twelve celestial Signs.

The oval Circumference of the Table represents well enough the Orbit or Path, which the Body of the Earth follows and describes in a Year round the Sun.

The whole Circumference is divided into twelve Portions, subdivided each into thirty Degrees, to make them correspond with the twelve celestial Signs, which I suppose to be over-against them among the fixed Stars. I have only drawn the compendious Figures of the twelve Signs on the Edges of the Table.

At a small Distance from the exact Middle of that Table, or terrestrial Orbit, and not just in the Centre, I put Half an Orange, to represent the Sun (S), the other Half of which may be supposed hidden under the Table.

I caused two Iron Pins to go through the Orange and the Table; the one (B) perpendicular to the Plane of the Ecliptic, and which I call the Axis of the Ecliptic; the other (C) inclined to the foregoing, and making therewith an Angle of 23 Degrees and a Half, or, which is the same Thing, an Angle of 66 Degrees and a Half with the Plane. This I call the Axis of the World: Not that the Planetary World revolves on that Axis, but only to give us here the Idea and the invariable Rule of the Direction we are going to assign to the Axis of the Earth, round which we are apt to believe that the World turns.

Let us now bring near the Edge of our Table the exact Middle of this little terrestrial Globe T, and moving it close

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to

* See the Figure.

to the Edge along the twelve Signs that divide the Oval, let us cause it to make a whole Turn round it. This very sensibly represents the Earth advancing in its annual Orbit round the Sun.

It is plain at first Sight, that if the Earth *T* be under the Sign of *Libra*, it will see the Sun under that of *Aries*. When it passes under the *Scorpion*, the Sun will appear under *Taurus*, and so on.

The apparent Motions of the Stars move from East to West, and in a Year's Time will complete this Revolution.

The Axis of the Ecliptic, because it is also the Axis of the terrestrial Orbit. It is a common Observation, that towards the East, at the Beginning of Night in Autumn, the *Hyades* form a large V in the Sign *Taurus*, and pretty near the same Place the *Platcon* or Cluster of the *Pleiades*. Some Months after, they appear to be pretty high at the Beginning of the Night, and from one Night to another they insensibly draw more and more to the West. They then appear to move in the Compass of a Year from East to West, because the Earth recedes from every one of them in the contrary Direction.

It is not thus with the Sun, I pass under, and not round the Stars, whereas I absolutely turn round the Sun. He resembles a Flambeau in the Middle of a large Hall. As I walk round the Flambeau, my Eyes see it on some of the Points of the Wall which bounds my Sight. If there are twelve Chairs round the Hall ranged in the following Order, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, when I shall pass by the Chairs 1, 2, 3, 4, 5, 6, I shall see the Flambeau before 7, 8, 9, 10, 11, 12; and when I pass before 7, 8, 9, 10, 11, 12, I shall perceive the Flambeau successively against 1, 2, 3, 4, 5, 6. It then makes, or appears to make opposite to me, the same Motions as I do. In like Manner, when we pass together with the Earth under the thirty Degrees of *Libra* in the following Order, A, B, C, D, &c. from West to East, we needs must see the Sun under the Degrees of *Aries* in the same Order, A, B, C, D, &c. from West to East. He must then appear to make his annual Course from West to East, and daily advance forward therein, according to the Succession of the Signs.

3. But while the Stars seem annually to move Westward, and the Sun annually Eastward round the Axis of the Ecliptic, the whole seems every four and twenty Hours to revolve from East to West round the Axis of the Earth: A Diversity which can proceed from no other Cause, but the twofold Motion of the Earth revolving in one Year on its Orbit round the Axis of the Ecliptic, and in twenty-four Hours on itself, that is, round its own Axis.

4. If the Portion of the six Southern Constellations is made a small Matter larger than the other Half, and the Sun be not exactly in the Middle of the Orbit, the Earth being seven or eight Days longer in the Southern Signs, shall see the Sun eight Days longer in the Northern, as is agreeable to Experience.

5. When the Earth, yearly advancing in her Orbit, keeps the Axis on which it revolves every four and twenty Hours perfectly right and parallel to the Axis of the Ecliptic, without inclining to either Side, then will the Sun and Stars always keep an uniform Aspect with regard to all Nations. Days will be neither shorter nor longer in one Season than in another; and Seasons will always be the same, or rather, there will be but one Season. The only Variation of the Heaven will consist in the annual Progress of the Stars towards the West, and of the Sun towards the East: But the Points of the Rising and Setting will not change. It is self-evident, that this is not the Economy of the World.

In order to understand, and to fix at once the Inequality of Days and Seasons, we need only to incline the Axis of the Earth twenty-three Degrees and a Half to the Axis of the Ecliptic; always keeping that Axis parallel to that of the World (C), and to observe well the Points of the Globe, where the Half which is enlightened by the Sun terminates. The inclining of the terrestrial Axis, the constant Parallelism of that Axis, and the greater or less Remoteness of the solar Horizon, with regard to that Axis, are the Source of the Inequality of Days and Seasons.

Let us, by the Assistance of a Figure, render this solar Horizon, and all its Vicissitudes or Changes of Place, more easy to be conceived. This Paste-board H, S, which I have made into Half a Circle, being perpendicularly placed on the Middle of the terrestrial Globe, may be a very just

Representation to you of the Edges of the inlightened Half which is towards the Sun, and of the obscure Half which is on the other Side. I shall call this Paste-board the solar Horizon. I have fastened the two Legs of the Semi-circle H, S, with two little Supporters in the Form of Shoulder-pieces; that we may be able to fix it, so as to make it stand at Pleasure, on what Place soever of the terrestrial Horizon we shall think fit. Instead of a whole Circle, which we should have to represent the Half of the Earth inlightened by the Sun, I have placed only a Semi-circle, that I may make it slide more easily, and put it wherever I please. Imagination may prolong it under the Globe, and supply the rest.

Let us place the Earth T under *Aries*, with the Axis N, M, parallel not to the Axis of the Ecliptic B, but to that of the World C; and the solar Horizon facing the Sun. In this Situation, the Axis of the Earth N, M, lies in the Plane of the solar Horizon, that is, that the Arctic Pole N may be exactly at the Border of the solar Horizon on one Side, and the Antarctic Pole M, at the South Part and Border of the same Circle, which marks the Limits of the Night and the Day. The Sun cannot inlighten any Thing more by his immediate Light. All the Points of the Earth, by revolving round that Axis in four and twenty Hours, visibly make Half of their Revolutions in the inlightened Part, and the other Half in the obscure Part. There is then that Day, *viz.* the 23d of September, an universal Equinox; whence the Sign, under which the Sun then seems to be, has borrowed his Name of *Libra*, or the *Scales*. By changing the Earth's Place, and bringing it to the first Degree of *Taurus*, you see that the inlightened Half is no longer the same. The Borders of it necessarily have slid, as it were, to other Points. We are obliged to place the solar Horizon in such a Manner, that it may exactly face the Sun. If you turn both the Axis of the Earth and the solar Horizon in such a Manner, that the one does not leave the other, it makes a Situation intirely like the foregoing, and you will again have an Equality of Days and Nights; since all the Points of the Globe will, in their daily Revolution, be as much above as below the solar Horizon. But if the Axis of the Earth N, M, shall remain parallel to that of the World C, while the solar Horizon changes its Place; then every

every Thing changes with it. The solar Horizon cuts the Axis at the Centre; so that one Half of the Axis M is on this Side the solar Horizon towards the Sun, and the other Half on the opposite Side. One of the two Poles is then more and more drawn into the inlightened Half, and the other sinks more and more into the obscure Part. We now begin to see, that the Points or Nations which turn together with the Earth towards the Pole that looks towards the Sun, may be longer in the inlightened Half than in the other. But this will become more evident by placing the Earth under the Sign *Cancer*. She then sees the Sun under *Capricorn*; and keeping her Axis parallel to her foregoing Situation, or to the Axis of the World C, she moves her Arctic Pole N from the Sun, and inclines her Antarctic Pole M twenty-three Degrees and a Half towards the Star. Had she her Axis parallel to that of the Ecliptic, she would see the Sun pass through all the Points of the *Æquator*: But having then her Axis on the Side M, inclined twenty-three Degrees and a Half towards the Sun, she sees him twenty-three Degrees and a Half above her *Æquator*; and as she on that Day, *viz.* the 22d of *December*, presents to him, in her Revolution from West to East, Points always distant twenty-three Degrees and a Half from the *Æquator*; the Sun will from East to West appear to delineate the Tropic of *Capricorn*. If thence the terrestrial Globe T successively advances under *Libra*, the Circle of the solar Horizon, in order to face the Sun, changes its Place a little, forms a smaller Angle with the Poles, and at last approaches them anew, or joins them again; when the Earth, being under *Libra*, sees the Sun in *Aries*. That Day, which is the 21st of *March*, the two Poles again cut the two Sides of the Horizon: Neither of the Poles is inclined towards the Sun, which by necessary Consequence must fall upon one Point of the *Æquator*: And as the Earth, in its Revolution, brings on all the Points which are at an equal Distance from the Poles, the Sun, on that Day, seems to describe the *Æquator*. Besides, all the Points of the Globe, by successively going up and down, are as long above as they are below the solar Horizon. They then have all twelve Hours Day, and as much Night, on the 21st of *March*.

The very next Day the solar Horizon changes its Place; but the Axis is not altered in the least. The solar Horizon does then begin to recede from it, and to leave the Arctic Pole N, which remains elevated in the enlightened Half; whereas the other Pole M begins to be immersed in the obscure Half. The solar Horizon every Day recedes from the Arctic Pole, till the Earth being placed under *Capricorn*, the Limits of the solar Horizon are distant twenty-three Degrees and a Half from the Arctic Pole N.

In this Situation, wherein all is very obvious, let us chuse three or four Points, or three or four Countries differently situated, in order to know what will happen on this Occasion to them. Let us, for Instance, take those under the Poles, those who live under the Polar Circle, those under the Tropic; and lastly, those who dwell under the *Æquator*.

1. Those who are under the Pole N, or that have the celestial Pole for their Zenith, have the *Æquator* for their particular Horizon. Now the *Æquator* here, is twenty-three Degrees and a Half below the Sun: They then see him revolve round them at the Height of twenty-three Degrees and a Half above the Horizon. There have been already three Months since these People came to the Verge of the enlightened Half, and they will be three other Months more before they reach the other Limit of that Half: They have then a Day of six Months long. They will be afterwards six Months, or nearly so, under the solar Horizon; and consequently all that Time without seeing the Sun. The People next the Pole, making their daily Revolution between the Axis and the solar Horizon, will be several Months together without touching the solar Horizon; and consequently have a Day several Months long. For this Reason they distinguish the Climates towards the Poles by Months, that is, in Degrees, or by Nations, the Days of which may, among themselves, differ by the Space of one or more Months.

2. What will happen to those who are under the Polar Circle? Since they are twenty-three Degrees and a Half distant from the Pole, and the Pole is as much distant

tant from the solar Horizon; all those who are under the Circle, or at that Distance from the Pole, shall on the twenty-second of June make their diurnal Revolution round the Axis, without passing under the solar Horizon. They will indeed come close, or graze upon, but not touch it: They then will have one Day four and twenty Hours long; and those, who are somewhat less remote from the Pole, may be several Days together without descending under the solar Horizon. There may then among themselves be distinguished by daily Climates, that is, Climates where the Increase of the Light shall come to one, two, or Daily Climates, three, or even more Days long.

3. But all such as are four and twenty Degrees, and more, remote from the Pole, even as far as the Äquator, make with the Earth a Revolution, the greatest Part of which is in the enlightened Half, and the smallest Part below. All these People have then unequal Days and Nights. None of them can have a Day twenty-four Hours long; because they all of them, some more, some less, cut upon the under Part of the solar Horizon. For this Reason, from the Äquator to the Polar Circle, they reckon the Increasing of the Light from Country to Country by hourly Climates; and they assign a new Climate, wherever the Day is on the 22d of June, Half an Hour longer than in the preceding Climate, beginning from the Äquator, where the Day is at all Times twelve Hours long.

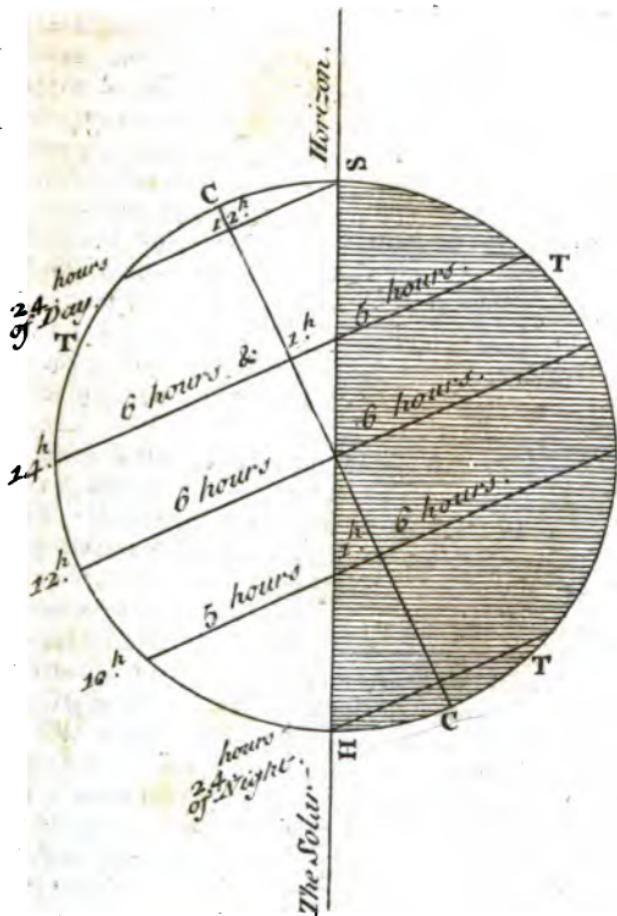
4. Nothing can be easier than the Determination of the Increasing of the Day, and of the Diminution of Nights from the Äquator to the Pole. Except the two Days on which the solar Horizon depends on the Situation of the earthly Axis, and when the Equinox is universal, the said Horizon every Day of the Year cuts the terrestrial Axis through the Centre, which is the same with the Centre of the Äquator. Each Point and Nation under the Äquator is then ever twelve Hours above, and twelve Hours under, the enlightened Half; the solar Horizon making with the Axis an Angle which always increases from the Equinox to the Solstice, where it is twenty-three Degrees and a Half. The Day must needs always increase to that Solstice, in the Half which

looks towards the Sun, and that Increase must be every Day greater and greater from the *Æquator* to the Pole.

Let us chuse out a Point or Place situated twenty-three Degrees and a Half above the *Æquator*, that is, under the Tropic of *Cancer*; for Instance, *Sienna* a City on the Confines of *Egypt* and *Abyffina*, being brought to the Border of the Solar Horizon, it will describe from West to East a Circle parallel to the *Æquator*, and on the 22d Day of *June* will see the Sun pass just over it in a contrary Direction. Suppose we have a mind to know, how long the Day will be at *Sienna*. A plain Circle T may here serve instead of a Globe. We may divide each of the Parallels that cross it into twelve equal Portions, to represent twelve Hours, or one Half of the daily Revolution. We then have, from the Point marked out 14, where *Sienna* is situated, to the Axis C, six Portions, or Hours. Let us reckon six other Hours from the Axis to the other Border: But we must subtract from these last six Hours, which is under the solar Horizon, since it is the Night which is about five Hours: There remains an Overplus, which you see in the Angle between the Axis C, and the solar Horizon H S, which is an Hour's Day more to be added to the other six. But we see in that Circle but one Half of the Revolution: We must therefore double the Sums, and we shall have for *Sienna* fourteen Hours of Day, and ten Hours of Night: And what I have said of the Northern Hemisphere, the Company may apply to the Progress of the Night and Day in the Southern Hemisphere. Thus all the different Motions of the Stars and the Sun, the Inequality of Seasons and Days, in a Word, all the Variations of the Heaven, are a plain Consequence of the annual Passage of the Earth round the Sun, and of her Revolution in four and twenty Hours round her own Axis, invariably directed pointing towards the North.

There remains but one Phænomenon, The Precession which I have not yet accounted for. The of the Equinoxes. celestial Signs, in a certain Number of Years, seem by little and little to quit the Points under which they were seen before, and with regard to the Points of the Equinoxes, to recede several Degrees towards the East. In order to account for this Precession, it will be sufficient to conceive, that in a very long Series of Ages,

The Measure of y^e Diurnal Arks.



Fr. Mynde Soule.



Ages, the Axis of the Earth insensibly changes its Place, and describes a very small Circle from East to West. So all the Motions of the Heavens, which are so contrary, and would be so difficult to be made to agree, were they real, want no manner of Reconciliation, because they are only apparent, and the Appearances have no other Origin than the Diversity of the Motions of our Earth. Let a Waterman, in order to amuse his People, make his Gondola whirl about as he passes before the Tower of St. *Mark*; his Passengers will see the Tower advance, then pass before them, then go back; and they at the same Time will every Moment see it turn round them. Must they therefore busy themselves about reconciling the several Motions of the Tower? Sure it did not stir from its Place, and all these Appearances have their Origin, both in the successive Progression, and in the turning of the Gondola.

But the Planet *Jupiter*, which now shews itself clearly, invites us to resume our Telescopes, and look out for the four little Moons which attend it.

Such is the Ground and Substance of *Copernicus's* Doctrine, which *Galileo* laid before the *Venetian* Senators, and of the Exactness of which he made them sensible, by shewing them in Nature, with his new Instruments, the Demonstrations of the same. But let us imitate his Modesty: What he gave only as a satisfactory Hypothesis, let us propose as a bare System, and confess, that it was attacked with Objections, which at first seem very much to lessen its Value, and its perfect Conformity to Observations.

The most puzzling Objection to *Copernicus*'s Doctrine was drawn from the Diversity of the Sizes and Phases under which the Planets would be seen, by receding from our approaching near the Earth. *Copernicus* confessed, that the Thing should indeed be as they said, and he prophesied, that one Day or other these Varieties would be discovered. *Galileo* has accomplished this Prophecy: Therefore the Objection becomes a Proof, and the Efforts, which were made to overthrow this Hypothesis, had no other Effect than to make it still more acceptable.

The second Objection which was proposed to *Copernicus*, and afterwards to *Galileo*, is, that if the Earth describes

an Orbit several Millions of Leagues broad, the terrestrial Axis, always parallel to itself, must correspond with such or such a Star, when the Earth is in *Libra*, and six Months after, when in *Aries*, must correspond with another Star, distant from the preceding by as many Millions of Leagues, as are contained in the Diameter of the Orbit. Nevertheless, we see the terrestrial Axis at one Time as well as another, constantly turned towards one Point of the Heaven, *viz.* two Degrees and a few Minutes distant from the Polar Star.

This Objection never puzzled *Copernicus*; because it was easy to see that the Distance of the Stars from the Earth is so immense, that twenty or thirty Millions of Leagues appear not sensible therein, and the two Points of the Heaven towards which the terrestrial Axis is turned at either Equinox, though they be really as distant from each other as the two Extremities of the terrestrial Orbit, yet appear to us no more than a single Point. Thus two Objects separated from each other by a Space of thirty, forty, or fifty Feet, seem to us but one and the same Thing, at the Distance of one or two Leagues.

Galileo, whom this Objection did not puzzle a whit more than his Master, with regard to this, presumed to prophesy, and he did it with the same Success with which *Copernicus* had foretold the future clearing of the first Difficulty: * “ I don’t despair (said the *Florentine Astronomer*, but one Day or other, some particular Tokens will be observed in the fixed Stars, by means of which they may be able to know, what the annual Revolution consists in: So that the Stars, as well as the Planets, and the Sun itself perhaps, will be summoned to appear in Judgment, to bear Witness concerning the Nature of that Motion in Favour of the Earth.”

Messieurs Caffini, Hooke, and Flamsteed, the greatest Names that we can quote for astronomical Observations, have for several Years together carefully observed, sometimes one of the Stars which pass through the Zenith, sometimes

* *Rem quædam olim in stellis fixis observabilem esse futuram, per quam cognosci queat in quo consistat annua conversio: ita ut fixæ non minus planetis ipsorum sole comparaturæ sint iudicio, ad reddendum testimonium bujus motus in gloriam terræ.* Dialog. de Systemate Mundi, 1635. P. 6. 575.

sometimes the Polar Star. They found, that both the Vertical and the Polar Star, in their greatest Elevation, appeared indeed under the same Degree of their Circle, as well when the Earth was under *Cancer*, as when it was under *Capricorn*; but that they both varied their Situations by several Seconds. The Stars have among themselves an invariable Situation. If then, in their passing again under the Meridian, they make with my Zenith, or with the Axis of the Earth, an Angle different from that I had in the foregoing Observation, it is because I have changed my Place, together with the Earth, which has passed from one Side of its Orbit to the other. As if from the Terrace of the Observatory I perceive the Steeple of *St. Dennis*, through the two Slits of the Sights of an Instrument, and one should place the Instrument a few Steps farther in a like Situation, or rather parallel to the foregoing. The Steeple shall no longer be seen through the Sights, and I shall be obliged to give them a gentle Thrust, to bring them again exactly over-against the Object. The Steeple did not change its Place; and its Removal to another Prospect or another Point of the Circle, is a Proof of the Observer's having changed his Place. One might be thence apt to conclude, that the Motion of the Earth makes a Part of experimental Knowledge, and that it is Matter of Fact.

The great Objection, which may be made against the *Copernican Hypothesis*, is (they will say) that it authorises the Irreligion of a great many Philosophers. Man, according to these, is very ridiculous to think that it is for his Sake that the Stars sparkle, the Sun rises, and Nature displays all its Magnificence. If the Planet *Jupiter* has four Moons, it is in order to convey Light upon it during the Night: But why should Light be conveyed where there were no Inhabitants? The Planets are then so many Earths, and if the Stars shine of themselves like the Sun, it is evidently because they light some other Planets. We are then much in the wrong, to attribute to ourselves the Use and Service of the Fires that sparkle in the Heavens: The Hypothesis of *Copernicus* proves, that they do not shine for us, but that we make use of them.

Whether we make use of them only, or whether they be made for us, is still one and the same Thing. Do

you think we can with any Reason find the least Difference in that? God alone knows, for what particular Purposes he designed each of these fiery Globes, which he in such Number, and with such Magnificence, has scattered around us. If we should suppose him to have there distributed several Intelligencies, in order to be praised by them; I see nothing in this Supposition any Way prejudicial to the Glory of God, or our own Gratitude: And though he should make them the Abodes of so many different Classes of Creatures, yet are we not under less Obligation to acknowledge the Advantage of our Condition, and to thank God for having granted us the Sight and Use of these Globes. The Inhabitants of *Paris* are not extravagant, when they think themselves happy, that our Kings have flung open to them the Gardens of the *Tuilleries* and *Luxembourg*, though those who dwell in these Places, and even Foreigners, have the Privilege of walking there as well as the *Parisians* themselves. God's Favours are not the less designed for us, because others may also share them with us in common.

But there is still something more: Good Sense and Truth are only to be found in the Language of the common People, who, seeing no other Being but Man, that can enjoy the Economy of this World, glorify God for having created it in Favour of Man; whereas Falshood and Error are visible in the Argument of the pretended Philosopher, who thinks, that the Multiplicity of Worlds should be a just Reason to criticise on the Language of the People. If there are Inhabitants in *Jupiter*, they have four Moons during the Night, whereas a single one is sufficient for us. Their Night is then quite different from ours. By their Remoteness, they must needs have their Sun smaller than ours; or if they have an Atmosphere otherwise formed than ours, they see it either larger, or otherwise coloured than we do. They then have another Sun. Astronomers have observed from the Direction of the Spots which revolve over the Disk of *Jupiter*, that the Axis of that Planet is perpendicular to the Ecliptic, and that the Globe makes its Revolution in ten Hours Time. They consequently have an uniform Season, Days perpetually equal, a Night of five Hours, and a Day as long; while our Days are of four and twenty Hours, and

our

our Seasons vary by a perpetual Alternative. Their Year is not ours. Twelve of our Years make their twelve Months. Every Thing then changes from one Sphere to another. Let each of them, if you will, be reputed as a World by itself and apart: Every one of these Worlds has its peculiar Structure and proper Advantages. The Inhabitants of one World do not thank God for the Order enjoyed in another. They have not the least Idea of it: They thank him for what they have received. We likewise praise him for our Sun, our Moon, our Heaven, our Year, our Atmosphere, and the special Providence by which he has secured to us the Enjoyment of that magnificent Prospect. We are the Centre of them; since we are the only People in the Universe for whom all these Cautions were taken: And as the Economy of our World is not only for us, but also for us alone; there is neither a Presumption nor a Mistake in the Persuasion Man has, that God had him in View, and vouchsafed to busy himself about him: Whereas the Error is palpable in the Notions of the false Philosopher, who, from the bare Suspicion of the Plurality of Worlds, immediately concludes, that he is no longer the Centre of the fine Order of this, and who, by multiplying them, fancies he will be able to lose himself in the Crowd, in order to avoid God's Goodness, and thus be exempted from the burthensome Duty of Gratitude.

If it be the whole Heaven that with an inconceivable Swiftneſſ turns round the Earth unmoved; this must be the Work of an infinite Power, always mindful of our Wants. If it is the Earth that turns, to procure all its Inhabitants the Services of the Light, and the Sight of the Stars; if each Planet on its Part revolves round its appointed Orbit; I here find again the same Power and the same Goodness, though with an Economy quite different. We may praise God for those wonderful Revolutions which serve us so regularly, without making any farther Inquiry into the Manner in which the whole is performed. But if some Genius, more elevated and more at Leisure, can add to the Knowledge of the Bounty that of the Performance; when God allows them a Glimpſe of it, and begins to let them into the Secret of his

his Works; it is a Confidence wherewith he honours them; it is a new Motive of Praise; and a Virtuoso, whom his own Way of considering Things makes ungrateful, is the most horrid of Monsters.

What a ravishing Magnificence, and at the same Time what an amazing Simplicity in the Work of the Creator, thus to have placed his Sun in the Centre of the Planetary World, and to make a Multitude of massy Globes float round it, which following without Lett or Incumbrance the several Courses prescribed them, perpetually receive from that glorious Star, their Light, their Colour, and their Life! Each Planet enjoys the Favours of the Sun, as though that Star were made for it alone, or there were in our Sphere as many Suns, and even Worlds, as there are Planets therein. A Parimony subsisting with Effects so fruitful, is in this Hypothesis an additional Character of Truth.

Equally and perfectly agreeable to Experience and Reason, it has, besides, the singular Advantage of accounting for and explaining all the Alterations, which Religion teaches us, have happened, or one Day or other will happen, in Nature.

When God keeps the Axis of the Earth directly placed on the Plane of its annual Course, the Inhabitants of the Earth have but one Season constantly the same, and enjoy both a long Life and a perfect Equality of the Air*. But he no sooner inclines that Axis, but the Waters immediately overflow the Earth: Seasons succeed each other on the Globe: The Unevenness of the Air shortens the Life of Men. It is scarcely the same Earth it was.

There is a Time, known to God alone, when he shall once again move this Globe. The Axis of it will no sooner be put in Motion, but Men will see the Heaven run like a Roller, the Stars fall, and Nature seem in the greatest Confusion. That Fall of the Stars, and that Flight of the Heavens, are a Language worthy him who made Man, and who alone knows the Reasons of the Appearances which he makes Man feel. Nothing more grand and majestic, nothing more exact than this Language! Men at the first Shock of the Earth will necessarily see the

* See the Letter at the End of the third Volume.

the Heavens change their Place and fly away, as they now see the Sun ascend, and from the Top of the Firmament descend to the Point of its Setting. *Copernicus* himself saw the Stars rise and go down; and he said with the rest, *the Sun rises, the Sun sets*, without Fear of offending Truth. His Hypothesis, which accounts for the Economy of the World, becomes here the Interpreter of Scripture, and makes us clearly understand, that the future Alteration shall, in all its Circumstances foretold, be as sensible as the actual Course of the Night and Day. It is a very rich Hypothesis indeed, which proves to be equally agreeable to Faith, to common-Sense, and the most frequent and reiterated Observations.

THE MICROSCOPE:

And the other.

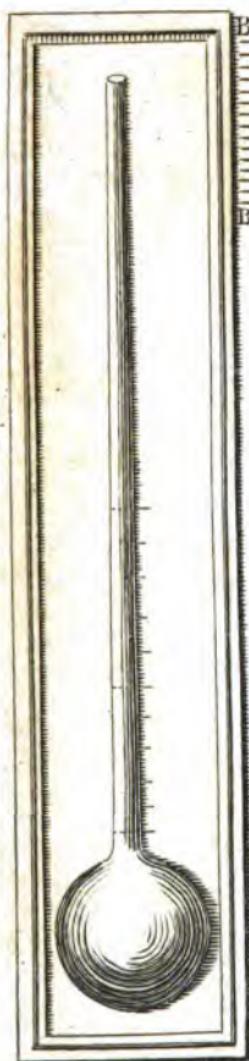
Inventions of the Moderns.

DIALOGUE VII.

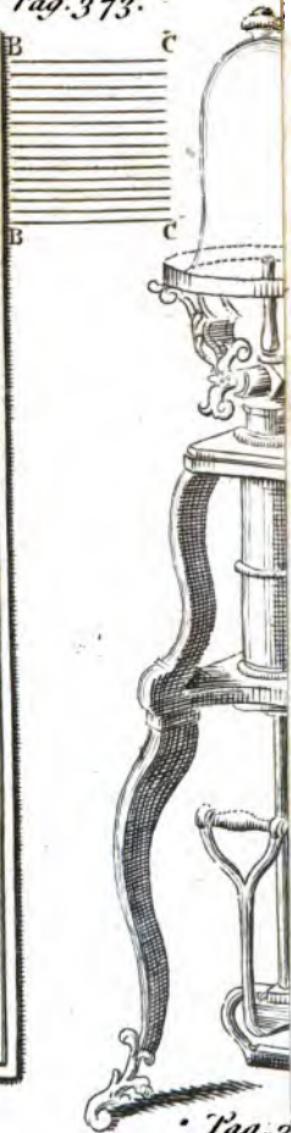
THOUGH Galileo and his Disciple *Torriceillus* were still full of the false Notions of antient Philosophy ; yet they must be looked upon as the Fathers of modern Physicks ; since they were the first who dared to maintain the Rights of Reason against the Authority of *Aristotle*, which stopped the Progress of Sciences, by tyrannizing in the Schools ; and they first introduced the Method so agreeable to Reason, of making every Thing refer to Experience. Naturalists, till *Galileo*, were no better than mere Talkers. Ever since his Time, and after his Example, they all turned Observers ; and it is on Account of his having observed what had escaped the Eyes of all the preceding Ages, that the *Italians* stiled him the *Lynx-eyed Virtuoso*.

The Statics, both that which sets Levers and Weights agoing, and that which gives Motion to Fluids, all Mechanics, Astrohomy, and Physicks in general, borrowed many considerable Helps from the Attempts made by *Galileo* on Motion, and by *Torriceillus* on the Air. I shall be contented with giving you an Account of the two finest Discoveries of each of them. That of the first is the regular Acceleration of heavy Bodies in their Fall.

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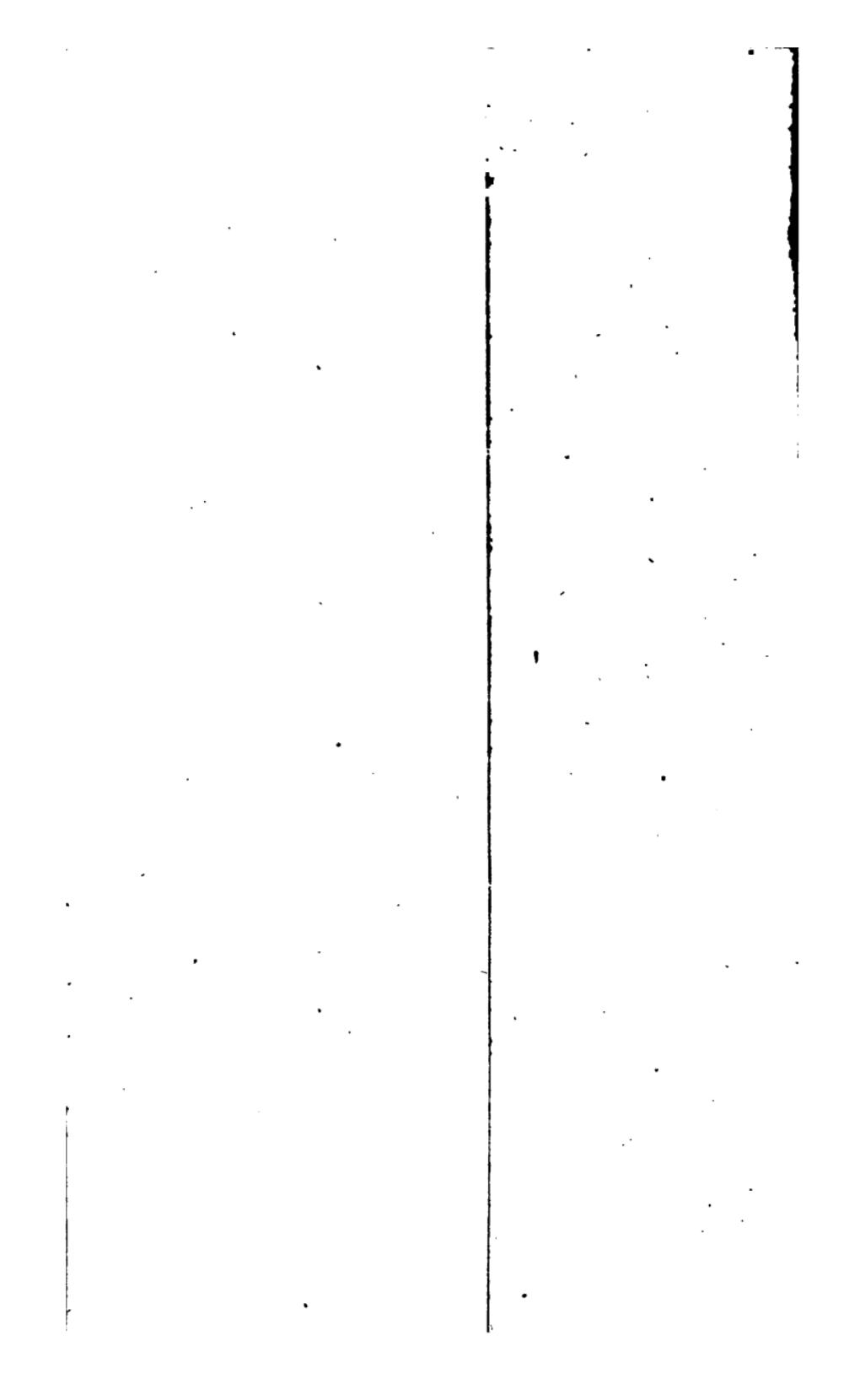


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Pag. 3

• Natura. 9.



I shall propose it to you after my own Method, and in as few Words as possible.

Let the Cause which brings down the Stone flung into the Air be what it will ; it is an existent Cause *. The Stone, at what Degree of Elevation soever it may be, receives the Impression of that Cause. That, which makes the Stone to fall, does then influence it every where, and at every Instant after it has left the Earth. Let us now from Reason see what will happen to a Stone cast into the Air, in Consequence of this very plain Principle. We shall be inclined to think ourselves to have reasoned well, if our Argument proves agreeable to Experience.

A Stone placed at twenty or thirty Feet Distance from the Earth, and left to itself, should (one would think) neither ascend nor descend ; since it has of itself no Inclination, or any Motion of its own. It moves only as it is pushed. Its Indifference, in the Choice of one Direction preferably to another, is still augmented by the Equality of the Pressure of the elastic Fluid of the Air, which, by pushing it as much towards the Heaven as towards the Earth, and in every other Direction, should for ever contribute to keep it in the same Place. However, we know that there is a very active Cause, be it what it will, which pushes the Stone downwards from above at every Instant, and at what Point of the Air foever it may be.

Any Body put into Motion, preserves as much as possible the Motion it has got. The Stone will then, during the second Instance of its Fall, and in all the following, as far as the Resistance of the Air will permit, preserve what Motion it has acquired in the first. But the same Cause, which pushed it at the first Instant, likewise pushed it at the second. It then adds a new Motion and a new Strength to the first, and its Swiftness is every Moment accelerated. The Proportion in which this happens is this :

Let us here represent Celerity by a Line. A Line consisting of only two or three Points shall represent a very

* See *Discorsi e Dimonstrazioni Mathematiche, intorno alla mecanica e i movimenti locali del Signor Galileo Galilei* [incluso].

ing, they will make four: Now, four is the Square of two, or the Number two multiplied by itself. If you join the five Perches of the third Second with the four Perches of the two preceding Times, they will make nine: Now, the Number nine is exactly the Square of three; for three Times three are nine. If you join the seven Perches of the fourth Space of Time with the nine preceding, they will make sixteen: Now, four Times four make sixteen. The total Sum of the Spaces gone through must then prove to be as the Square of the Times, or if you will, as the Square of the Celerities, which increase as the Times. What we have just said of the Acceleration of falling Bodies, we may say in a contrary Sense, of the slackening of whatever ascends: Because the Force which raises it is incessantly diminished by the Cause of Gravity. Therefore, if you throw a Body into the Air with a Force equal to the five Degrees of Celerity, which it should acquire from Gravity in falling during five Seconds, and without taking Notice of the Acceleration, which in the Fall proceeds from the acquired Motion; that Body thrown will have but four Degrees of Celerity at the second Second, three at the Third, two at the Fourth, and the remaining Force expires with the fifth Second.

What we have just established by reasoning on the Acceleration of heavy Bodies is not a bare Opinion. It is a Phænomenon for the first Time observed by the celebrated Galileo, and confirmed by Experiments made at the Observatory, by the Help of the Hole contrived in the Vaults, from the Upper Terrace down to the Bottom of the Caves.

Of the Pressure
of the Air, and
the rising of
Liquors in
Pipes void of
Air.

The Experiment, which makes for the Glory of Torricellius, is the rising of Liquors in Pipes void of Air. The Conduit-makers of the Grand Duke had been thought themselves to make Pipes higher than those wherein Waters usually rose.

But as they did not experience, from these Pipes of a new Structure, the Assitance expected from them, and the Pump refused its Service when the Water was to be raised above thirty-two Feet, they communicated the Thing to Galileo, and asked him the Reason of it. Our

Philosopher.

Philosopher was for that Time surprised, and unprovided of an Answer. However, he put a good Face on the Affair, and gravely replied, that Nature abhorred a *Vacuum* only to the Height of thirty-two Feet. The Conduit-makers took this as a Principle; and that Rule, false as it was for the Cause pretended, yet carried on their Works perfectly well, as to the expected Effect: So true it is, that a Man may, without any great Danger, be mistaken with regard to the Cause of what he does, provided what he executes be directed by Experience. Experience is indeed our true Physics.

Torricellius *, vexed at the Water's refusing to ascend more than thirty-two Feet in a Pipe void of Air, made a new Experiment on a massier Fluid. He filled with Mercury a Pipe well stopped at one End; he set it up with the open End immersed in a Vessel of Mercury; then withdrawing his Finger without putting the Orifice of the Pipe quite to the Bottom of the Vessel, he saw the Mercury in the Pipe come down, and leave an empty Space at Top, and remain suspended at the Height of twenty-seven Inches. How! said he; Nature abhors a *Vacuum* only to the Height of thirty-two Feet when it is Water that ascends in a Pipe void of Air; and only to twenty-seven Inches when it is Mercury! *Vacuum* does not frighten her beyond these Measures! But why does she fear it to more than twenty-seven Inches, when it is Water that rises? Very likely this Horror of Vacuity is an idle Fancy, a mere philosophical Cant, which we take for good Coin without understanding it. Let us endeavour to find out something more satisfactory. His Disappointment and repeated Experiments led him at last to a very ingenious Conjecture. This Diversity of Elevation in two very different Liquors, appeared to him to proceed from the Diversity of their Weight. For, though neither he, nor perhaps any other Philosopher living, ever knew what Gravity is, yet it exists: It hurries us away: It crushes us: It is a most real Effect. As he was then searching what Weight might thus counterbalance these two Fluids, he thought Nature hinted to him that a Column of Air, correspondent to the Orifice of the two Pipes, might perhaps hinder the Fluids from falling, and keep them

them up at unequal Distances, because the twenty-seven Inches, of Mercury being very likely of the same Weight with thirty-two Feet of Water, which is a rarer Kind of Matter, the Column of Air might prove equivalent to either of these fluid Masses. This Conjecture, as well as the double Experiment of the Pipes, soon spread abroad. Mr. *Pascal** improved the Experiments, and gave the Conjecture an Air of Demonstration. Nothing appeared to him more satisfactory than the Experiment made by his Direction on the *Puy-de-dome*, a Mountain near *Clermons* in *Auvergne*. The Column of Air being shorter at the Top of that high Mountain than it was at the Foot, he thought it ought to weigh less on that Account; and they found, that in Conformity to his Expectation the Mercury, which at the Bottom of the Mountain maintained the Height of twenty-six Inches, was come down to twenty-three at the Top. Among other very sensible Means, he employ'd a crooked Pipe, as you see it in the Figure. The End marked A is hermetically sealed up. The Orifice B is exactly covered with a Piece of a Bladder. The Pipe, being full, must be turned up-side down as usual. When you take your Finger from the End dipped into the Mercury, what will happen? If the Air weighs or presses, it will keep up the Mercury of the Pipe just at the Height of twenty-seven or twenty-eight Inches in C, and the Mercury which is in the crooked Part D, having no Relation to the Air, will, on each Side, put itself in an Equlibrio in the two Branches. But if you open the Orifice B, the Air must precipitate the Mercury from the Pipe directly into the Vase, and raise the Mercury, which is in the crooked Part D, up to A. And this is indeed what happened in all the Trials made of it. However, I don't know whether it is perfectly certain, that this Effect of Fluids in *Vacuo* proceeds from the Weight of the Air. It has been since acknowledged, that the Air has a very powerful Spring, and that Spring possibly is the true Cause of what is attributed to the Pressure of the Weight.

The Invention of Some Virtuosoes, who had left in a certain Place a Pipe of this Kind, whose neither End was immersed in a Vessel of Mercury, soon perceived that the Mercury, which was suspended

pended in the Pipe without falling out, was not always at the same Point; but that it rose in dry Weather, and sunk at the Approach of Rain, and sometimes was suddenly agitated at the Approach of Storms. All these Observations were reduced into Rules. They put a Paper with Degrees marked upon it, or a Scale of several Marks, towards the highest Part of the Fluid, in order to compare the Progress of it, and thence to deduce some Prognostics on the Changes of the Air. They thought they had found some that were pretty certain for the Space of one Day, which would already be of very important Service; and instead of the little Vessel or Cistern separate from the Pipe; they added to the latter a Glass Vial full of Mercury, making the Pipe somewhat elbowed or crooked, and keeping the Vial open at Top, freely to receive the Impressions of the Air. As that Bottle was three or fourscore Times broader than the Pipe; if the Impression of the Air by its Alterations makes the Liquor of the Vessel to descend one Point, there enters of Necessity a great many Times as much into the small Orifice of the Pipe; so that the rising or sinking of the Mercury in the Pipe, becomes thereby extremely sensible: In a Word, they found out the Barometer.

Many great Inquiries were made into the Reason, why the Air, which one would think ought to be heavier at the Approach of Rain, suffers the Mercury of the Pipe to sink, instead of raising it higher by the Pressure of that of the Vessel.

To the common Conjectures I shall add one, which will at least have the Merit of not being long. There remain always between the Tube and the Mercury poured into it, a great many Bubbles of Air, several of which fill the Top of the Tube after the Mercury leaves it. These Bubbles of Air are always the same in Quantity: But the Quantity of Fire that creeps into or out of it may vary: They therefore may contract or dilate at the Approach of Rain. The minute Drops of rarified Water, which every where spread, are squeezed and stopt by the Sides of the Glass. The Fire, which gets out of them, easily insinuates itself where the Water cannot enter, and dilates the Bubbles of Air it finds in the empty Part of the Tube, so as to press somewhat gently that Surface of the Mercury,

cury, which then yields and finks. The same Thing will happen, if you present a burning Coal to the upper Part of the Barometer; and if the Mercury does not fink there in hot Weather, it is because the Heat does not circulate less in the Air that presses the Mercury of the Vessel, than it does in the Bubbles in the Vacuity. It is then probable, that the lowering of the Mercury at the Approach of Rain, is owing to the accidental Fire which insinuates itself into the Bubbles of Air in the Pipe, by quitting the Bubbles of Water which are condensed on the Outsides of the Glass. This Suspicion seems to be countenanced by the small Lightnings, which that Fire sometimes causes, when the Barometer is jogged in the dark.

The Invention of the Thermometer. A Dutch Peasant, named *Drebbel*, is reputed in the Beginning of the seventeenth Century to have had the first Idea of another Instrument, which commonly is annexed to the Barometer, and is called the Thermometer, because it measures the Degrees of the Heat, as the other does those of the Weight or Spring of the Air.

The Thermometer is nothing but a round Bottle, having at Top a very long and small Neck or Pipe, whose inward Diameter is twenty, thirty, or as many Times as one thinks fit, narrower than the Body of the Bottle; so that if you close the Pipe at the Lamp of an Enameller, after having filled the Bottle and a Part of its Neck with coloured Spirit of Wine, the Liquor cannot swell and mount one Point in the Body of the Bottle, without ascending twenty or thirty Points in the small Tube. Spirit of Wine is fitter than any other Liquor for this Purpose; because it never freezes. The Fire, which rolls in the external Air, cannot increase therein, without insinuating into whatever it meets with, and consequently into the Liquor contained in the Glass Ball of the Thermometer. It cannot enter into the Body of the Ball, without dilating the Spirit of Wine; and if it dilates it ever so little, it sensibly causes the small Thread of that Liquor to ascend in the Tube. On the contrary, if the Fire lessens either in Quality or Activity in the Body of the Air, it proportionably diminishes in the Mass of the Spirit of Wine. This condenses a small Matter; and if the Diameter of the Ball is to that of the Tube as 1 to 20, the Liquor of the

Ball

Ball cannot condense the quarter Part of one Line, but the Thread of the Tube sinks at least twenty Quarters of one Line, that is, five Lines. A graduated Scale, glued on the Board wherein the Tube is set, shews the Dilatation or Contraction of this Liquor. But the Fancy of the Workmen being the only Rule that determines the Proportion of the Ball to the Tube, that generally determines the Point from which the Numeration is to begin; that also determines the Choice of a Liquor more or less capable of being dilated; that, in short, assigns to the Degrees their Measure: The natural Consequence of this Variety in the Construction is, that we hardly know what we say, when we mention such or such an Elevation of the Thermometer. It is self-evident, that the Thermometer of two different Towns, or even Houses, will never speak the same Language; so that they can never be compared together.

Mr. *De Reaumur* *, by reducing the Construction of the Thermometer to such Rules as make it uniform and constant, has enabled us to compare the Advices of the Thermometer of *Paris*, with those given by the same Instrument at *Rome*, *London*, or *Constantinople*.

The Use of the Thermometer is not an Amusement of mere Curiosity. It serves to determine the Degree of Heat we think fit to give to the Air of a Room, the Water of a Bath, and a hot Green-house; whether we intend to forward our ordinary Plants, or to preserve any foreign Plants in them. This Instrument affords us an infinite Number of Experiments, wherein we are exactly to judge of the Degree of Heat of Fermentations, and of the Degree of Cold in what has been artificially frozen. In short, it is most particularly from the Comparison of Thermometers of an uniform Construction, and placed in different Countries, that we may draw Consequences fit to bring the Knowledge of the Air to its Perfection.

In order to judge rightly of the Variations of the Heat, the Thermometer must be put in a free Air to the North, and in Places inaccessible to the Sun, to great Reflections

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* See his excellent Memoir, 1730, or the Explication found upon the Thermometers of that Construction, at the *Abbe Noller's* in *Paris-ans*.

of the Light and the Heat of Chimnies. The North is likewise the most favourable Exposition for the Barometer.

The Invention of the Air-Pump. There is another Machine designed to demonstrate the Spring of the Air, and to inform us concerning the Relations that Element has with whatever breathes or vegetates; or rather with every and all the Parts of Physics. For is there any Thing on Earth, into the Composition whereof Air does not enter, and make its Action sensible? Is there any Element with which it does not unite? That admirable Instrument called the Pneumatic Machine, or more commonly the Machine of Vacuum, was invented in *Germany* about the Middle of the seventeenth Century, by *Otho of Guerric*, a Consul of *Magdebourg*, and brought to Perfection in *England* by Mr. *Robert Boyle*, a Member of the *Royal Society*.

On a Stand of any Form, is horizontally placed a round Copper or Brass Plate, with a Hole in the Middle, garnished with a Buck or Sheep-skin, and designed to support a Glass Cap, or any other Recipient you think fit to lay upon it. There is under the Plate the Body of a Pump, into which you receive the Air of the Recipient, as you let down the Piston or Sucker. The Cock being turned, and exactly stopping all Communication of the Pump with the Receiver, lets the Air out through a Groove contrived at the Side of the Key. When the Sucker is raised up again, and the Air dissipated, they open the Channel again, and by new Strokes of the Sucker, exhaust as much as possib'e the Air from the Recipient, which the Pressure of the Atmosphere fastens down very strongly to the Plate; the little Air that remains under, being too much unbent to be able to resist that Pressure. You immediately see some Vapours floating therein, which are so many Particles of Water, wherewith the Air is always furnished, and which run together again for want of the Support of the Air, which by rarifying them made them also invisible. If you put under the Recipient either withered Fruits, or a flaccid Bladder tied and loaded above with a Weight of several Pounds, the Skin of the Fruits stretches and becomes smooth: The Bladder swells, and makes the Weight rise: A Bird or any other Animal immediately falls into Convulsions

Convulsions therein : A Fish experiences a most violent Tension : His Eyes swell, and his Air-vessel bursts. The inward Air which dilates within their Body, because there is no longer any Air that presses the Animal without, is to it at first in lieu of a violent Emetic, and would kill it, were not the Air immediately restored to it again.

From these and a hundred other Experiments it has been found, that the dilated Air fills a Space several thousand Times larger than it did when it was compressed. They have begun to perceive the Power of the Air, in all the Nutritions of Animals and Plants. But of all the Advantages that have been procured by this Invention (and these indeed are numberless) none perhaps is greater than that of perceiving the Artifice by which God has made us to live in a Fluid which we do not feel, by giving the small Portion of the Air within us a Tendency towards dilating, every whit as powerful as that the external Air has to crush us by a Pressure capable of breaking the Ribs of our Bodies, and of suddenly bringing the Back and Breast-bone close to one another. By this truly wonderful Equilibrium, the Muscles which stretch the Arm of Man, and those that move the Wing of a Gnat, exercise their Motions without any Resistance, notwithstanding the enormous Pressure of the Body which is round them : And whenever that external Pressure increases or diminishes by the Concurrence of the Water, the Fire, and the Winds, there happen in the Vessels of Animals and Plants such Alterations as determine the good or bad Constitution of them. All the Progresses of experimental Physics are then to us Demonstrations of the two following Truths: The first is, that God maintains the World by the general Law of a simple and regular Motion; the other, that the very minutest Globule of Fire, Water, or Air, is a Machine framed with Art, and by a special and determined Will.

Both these Truths, the Basis of sound Physics, will borrow the utmost Degree of Evidence and Perspicuity, from the Discoveries that have been made by the Assistance of the Microscope.

It is thought that the *Hollanders*, who had with Success wrought the Glasses that draw remote Objects near, were the same that first looked for, and found out some Means of magnifying

The Invention
of the Micro-
scope.

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fying Objects. Mr. Hooke in *England*, Messieurs *Salviati* and *Malpighi* in *Italy*, Mr. *Leeuwenhoek* in *Holland*, and Mr. *Joblot* in *France*, have applied themselves very much both to the improving of lenticular Glasses, and the Manner of mounting them; and have communicated a thousand Observations to us equally curious and important. The Microscopes, which are the most approved for their Structure and Effects, are those of Mr. *Edward Scarle* of *London*, of the *Abbe Nollet*, and of Messieurs *George* at *Paris*. *Leeuwenhoek*'s famous Microscopes were nothing but very small Drops of Glass melted at the Lamp of an Enameller. When you want the Instrument, you may at any Time, and in a Moment, procure it, by piercing with a Pin a very small Piece of Lead, and by filling the Aperature with a very little Drop of Water, which you are to put into the Orifice with the Beak of a clean Pen. If that Drop remains round like a Bubble in the Pin-hole, it becomes a Lens, the Focus whereof being extremely near, it will prodigiously magnify any small Object you shall present to it: And the Loss of that excellent Microscope may be repaired at a very small Expence, by one that is equivalent, or perhaps superior to it in Goodness.

Here, together with an unknown World, we discover new Motives every where to adore and be sensible of the Hand of the Creator. From a vague and extravagant Prejudice, oftentimes strengthened by the very Principles of our Masters upon the Subject of Corruption and Generation, we attributed to vile Matter the infinitely honourable Privilege of producing Animals and Plants. I never would call such a Philosophy a sacrilegious Impiety; since we can never be too sparing in the Use of odious Appellations: But to take from God, and to attribute to a Fruit grown sour the Glory of producing an Insect, which shall afterwards bring forth another like itself, is saying, that Motion may organize a Body, prepare a Brain, make Nerves issue from it, constitute a Contrast of Muscles, construct Lungs, a Heart, a Stomach, and Bowels. Does not the Philosopher, who gravely teaches the Possibility of these Generations, shew a perfect Readiness and Disposition to admit *Epicurus*'s Cosmogony? But instead of arguing here against the second Causes of the Schools, and against their directive Concourse; let us take a good Microscope

croscope in Hand ; it will confute all those empty Formations which are attributed to Matter, and every where unveil to our Eyes the immediate Operation or Action of a Wisdom which daily produces every Thing, or from one Day to another unfolds what she had in the Beginning created in little ; that it might successively again produce and perpetuate itself through all Ages. The Microscope shews us all these Insects coming out of the Eggs that contained them. There are now a days no Plants, whose Seeds it does not discover to us. The very Mushroom has its own ; and the Dung, which may very well nourish it, can no longer generate it. Nay, something more was done. The imperceptible Dusts, which from the Top of the Stamina of Flowers fall round the Tufts of the Trunks or Snout that stands on the Capsula of the Seeds, in the Microscope become Bodies of a regular Figure, and constant in every Species. The Dusts of Mallows are little Balls bristling with Prickles, like the Shell of a Chesaut. The Dusts of Poppies are Balls wholly transparent, a single black Spot excepted, where all the Threads of a fine Network, which surrounds them, center. The Scale of a Sole, the Smallness of which makes us overlook it, and which we swallow without our Knowledge, is a Work of most admirable Regularity. The End, which fastens this Shell to the Sole's Back, is armed with twelve or fifteen small Points, with which it is as it were pinned to the Flesh of the Fish. There is not one single Fish, whose Scales are not more beautifully woven than the Master-piece of the most ingenious Basket-maker. The Fibres, which compose the Scale of a Pike, are woven in a Manner quite different from those which we admire in the Scale of a Carp or Perch : But one Order and Texture invariably reigns in all the Scales of the same Kind. No less Regularity is found in the Structure of the Feathers of Birds, in the Fibres of the Flesh of the several Animals, in the Make and Composition of the several Kinds of Wood, and in the Figures of the different Salts. From the *Cape of Good Hope* to *Suez* ; from the *Isthmus of Suez* to the remotest Parts of *Tartary* ; in short, from *Tartary* and *Labrador* to the *Terra Magellanica*, whatever exists has a constant Form, and an invariable Structure, notwithstanding the Variety of Foods, and the Multiplicity of Circumstances.

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cumstances. The Mixture of the Species may indeed perpetuate and multiply some certain Varieties in the outward Form, and in the Inclinations of Animals. The Passage of the Dust of the Flower of one Pear-tree, into the Pistillum of the Flowers of another, may also make a Mixture of Properties, and enrich us with some new Kind of Fruits: But the Genus of both the Animal and the Plant is never to be destroyed, and the Motion of accidental Causes, which never alters them at Bottom, or intirely changes their Nature, can by no Means have formed them. The Microscope gives this important Truth a much greater Degree of Evidence, by enabling us to perceive Dusts and Grains in those very Plants which are of themselves imperceptible. The Use of the Dusts, employed in an uniform Manner to render the Seeds fruitful in all Plants whatever, shews a general Design; and the Variety of the Execution of it still better shews, that this is not the Work or necessary Impression of blind Motion, but the Choice of a free Wisdom, which has in such or such Plants united the Dusts and Seeds on the same Stem; and in others put the Dusts on one Stalk and the Seeds on another: An Artifice which can indeed never be done by either Motion or Attraction.

The Microscope, which in every known Being brings us from the same Vessels to the same Fibres, and afterwards shews us the same capillary Fibres therein, convinces us of a primordial Delineation, and of an Organization, which, in the minutest Animal, as well as in a whole World, can have no other physical Cause than God himself.

This is not a Place to speak to you of the Structure of Microscopes, or of many other wonderful Machines, which are every Day invented. I shall defer giving you the Principles of them, till I entertain you about the geometrical and mechanical Rules, which make up the full Certainty of them. It is impossible now to pursue a more particular Enumeration of the Successes of experimental Physics, either in the Assistances it endeavoured to procure our Ears and Eyes, or in those it supplied us with, by the Observation of the internal Parts of the human Body. Chemistry alone should deserve to be studied apart. One might make up a reasonable Volume of the bare List of the Services

Services which Botanicks do us every Day, by shewing us new Remedies, by imbellishing our Gardens with new Shrubs for Flowers, by enriching us with new Vegetables and Fruits, by facilitating the Means of keeping up our impaired Forests; by supplying Turners, Joiners, and Inlayers, with Woods of a richer Colour, or fit to be rendered more smooth; by supplying Painters and Dyers with Seeds, Gall nuts, Fruits, Leaves, Woods, Roots, and Oils fit to bring Varnishes to Perfection, and to diversify the Ornaments which we so much admire in our Attire, Furniture, and Churches.

A single Fact will make you judge of the Merit of Botanicks. A few Sprigs of Coffee, having with their Roots been carried from the Garden of the Plants of Leyden to Java, and from that of Paris to Martinico and then to La Cayenne, have already begun to yield Millions, and almost wholly freed Holland from the Contagion of the Scurvy, by rendering the Use of Coffee universal and common there. But I shall give you a sufficient Account of all the Helps which we derive from modern Physics, by acquainting you in a few Words with the Establishment of those illustrious Societies, which professedly make it their Business to procure us these Helps.

The Success of the Observations and Experiments of Galileo and Torricellius, in the Time of King Lewis the Thirteenth, induced a Multitude of Virtuosoes to attempt the same Things in France. The Exactness, quick Penetration, and singular Clearness of Mind of Mr. Paschal, who carried the same Experiments much farther, made him caressed and courted by the greatest Naturalists of that Time. As young as he was, Crowds of learned Men flocked together to hear him speak. By Degrees, a Society of Virtuosoes gathered round him, who regularly held their Conferences on certain Days, and mutually communicated to each other the Fraits of their particular Studies. Next to Mr. Paschal, the most considerable of these learned Men were Messieurs Fermat, Robertval, Gassendi, Descartes, Father Mersenne a Minim Monk, and a few English Lords. Mr. Oldenbourg, who was one of the latter, being returned to London, there introduced the Method of the like Conferences. This Association for the Improvement of solid and evidently useful Studies,

easily found many Favours among the *English* Nobility ; not only because they found in it Means of Comfort, or of avoiding Suspicion under the Dominion of *Cromwell* ; but above all, because the Nobility of that Nation look upon Ignorance as a Reproach ; and never think themselves happy, but in Proportion as they busy themselves usefully and reasonably. The same Encomium of the *English* Nobility was made by *Erasmus*, above two hundred Years ago.

The evident Advantage of these Societies determined, almost at the same Time, King *Charles the Second*, and King *Lewis the Fourteenth*, to render them durable and permanent, by giving the *Royal Society* *, and the *Academy of Sciences* †, a House, a Fund, and proper Regulations. The Transactions of both these Societies are nearly so many annual Experiments ; and it may be said, that it is from them that we have our best Physics. After their Example, were successively formed the Academies of *Florence* and *Boulogne*, of *Montpelier* and *Bourdeaux*, of *Leipsic* and *Berlin*, and of late, those of *Peterbourg* and *Seville*. These two last make us hope to obtain the Informations which we wanted, both on the Particularities of the Northern Parts of *Europe* and *Afia*, and on those of both *Americas*.

All these Societies gave, and every Day give Birth to an infinite Number of painful Observers ; who, instead of tediously repeating, or of disguising with a new Outside the Learning of their Predecessors, constantly proceed from one Experiment to another, and every Day afford us new Facts and Truths, little known in former Times. The Title of Geographer or Astronomer, of Botanist or Geometer, or any other, assumed by any Naturalist, who designs to have Admittance into the new Academies, is the Profession of the Service he obliges himself to do the Public. By this Means, Sciences, formerly so dull, so languid and melancholy, are now become as active, as brisk, and as strictly adapted to our Wants, as Arts, even the most mechanical, can be.

We are indebted to Mr. *Huygens*, one of the *Academy of Sciences*, for the Perfection of Clock-making. The great

* In the Year 1663.

† In the Year 1666.

great *Cassini* shewed us the Ring of *Saturn*, and four of the little Moons which attend it. The practical Part of Astronomy, which is of greater Concern to us than the most sublime Theory, is now come, in his Hands, to a greater Degree of Exactness than it ever had before his Time. In the Year 1663, Mr. *James Gregory**, of Aberdeen in Scotland, gave us the Idea of the reflecting Telescope; and it is that which *Messieurs Paris* now make with so much Success, both in little and in great. Some Years after, Sir *Isaac Newton* made us acquainted with the Wonders of Light. Mr. *Malpighi*, a Physician of *Boulogne*, is the first who rightly and accurately observed the progressive Unfoldings, both of the Chicken in the Egg and of the Sperm in the Seeds, and generally of the Stalk, of the Barks, and of the Buds in their *Capsule* or Cases. *Messieurs Morland* and *Geoffroi* are those who, being guided perhaps by the Advice of *Seneca* and *Pliny*, have put in a better Light the Relation which is found between the Dust of the Stamina, the Flowers and the Seeds contained below the Pistillum.

Mr. *De Tournefort*, Mr. *Ray*, and *Messieurs De Jussieu*, have by their indefatigable Cares put in good Order the Knowledge of Plants, which was horridly confused before. The two last, infinitely dear to the Public for the vast Extent of their exquisite Learning and Knowledge, are still more so on Account of their eager Zeal in forming good Philosophers. Mr. *Lémeri* served us extremely by his Dictionary of Drugs. Mr. *Pagot d'Onzenbray*, Mr. *Bonnier de la Mosson*, Sir *Hans Sloane*, and the Duke of *Bourbon*, by their rich Collection of Curiosities, of marine and terrestrial Productions, of Minerals, Instruments, and Machines of all Kinds, have nobly animated and assisted Natural History, Mechanics, and all Arts in general. Their Cabinets are the true Magazines of Natural Philosophy; and offer Virtuosoes not only an amusing Spectacle, but also a commodious Repertory of whatever may be serviceable to Mankind, excite Curiosity, and be the Subject-matter of as many Experiments.

* See his *Optica Promota*, printed in the Year 1663.

The Description of a good Observer. It is not enough, my dear Chevalier, that I have informed you of the finest Discoveries of modern Physics, and given you a Relish of that Science, which is fitter than any, nobly to fill up the leisure Hours of a rational and judicious Mind. The History I have given you would still be insufficient, did I not conclude it with the Picture of such an Observer as may serve you as a Pattern. I know one of that Kind, and you know him too, since I have often observed to you, that if I had sometimes amused you by certain and delightful Observations, I was particularly indebted to his Works for them.

He is a Geometrician; because he knows, that no great Progress can be made in many Parts of Natural Philosophy, without the Assistance of Geometry. But he does not dwell perpetually upon Geometry, or is for ever intent upon Lines; nor does he affect publicly to talk Algebra with three or four European Philosophers who may chance to understand him. When Necessity requires it, he has Recourse to his mathematical Case of Instruments; and, but in Cases of Necessity, he loves to treat on such Subjects as are universally understood. What he says about them, is always so new, and uttered with so much Comeliness and good Grace, that every Woman listens to him with the utmost Satisfaction. Nay, his Generosity is such, that he pitches upon such Matters as may concern Artizans themselves.

He is a great Observer, and his Learning is rather about Things of particular Examination, than about general Subjects: Having from long Experience been convinced, that there is scarce any Thing but Uncertainty and Unprofitableness in general Physics; whereas the Consideration of particular Subjects most commonly leads us to certain Discoveries and useful Operations.

Difidence is the chief Character of his Method of observing. He carries the Exactness of his Researches to the utmost Scruple: And instead of being satisfied with one single Fact, though he saw it very plain, he turns over and over, and every Way considers the same Subject: He makes it pass through so many Trials, that very often he by the Way finds Things still new, together with the Confirmation of his first Discovery. One might be apt to think,

think, that such a Patience must coil a brisk Genius, and which is greedy of acquiring Learning, very much: But this Exercise has rendered him so very sharp sighted in the Works of Nature, that he at the first View perceives to what End such or such a Thing tends, from the Analogy it has with other Things perfectly known to him. By the Beginning of an Experiment, he guesses what the Sequel of it will be. From the first Motions he sees any unknown Animal make, he foretels in what the whole Operation of that Animal will end. But though he is used always to see his Predictions accomplished; yet he never thinks he has seen any Thing, till he has repeated and varied his Experiments. He looks upon the minutest Things in Nature as so many Miracles, which are not to be admitted, till they have been fully ascertained, and made clear beyond all Doubt.

The Aim of his Observation is, as far as in him lies, to make them refer to our Wants. I know that he sometimes aims at no more than a laudable Curiosity. There is perhaps nothing more than a bare Amusement to be hoped for, from what he tells us of the Formation of Pearls, Shells, and Stones, of the Beginning and Increase of Coral, of the Light which some certain Shells cast *, of the Republic of Wasps, and of the Work of a vast Number of Insects; but Amusements like these are indeed very noble; and even in these he may be said to arrive directly enough at Utility; since reasonable Diversions make a Part of our Wants.

As for the rest, this agreeable Virtuoso every Minute has our Welfare in View. One would think, from his constant Attention to find out whether such or such a Thing might not be of Service for promoting the Fertility of Lands; whether another might not procure us some new Dye; whether a third might not be good for Iron Works; whether such or such an Earth might not imitate *China* Ware; whether such or such a Sand might not be of Use to Architects or Glass-makers; whether such or such Means might not assist a Housewife or a Mother, in preserving her Stuffs from Moths, or her Children from the biting of Bugs: From all these his Cares, I say, one might be apt to think, that he is

ashamed of knowing any Thing from which Mankind can reap no Benefit. He never thinks himself debased by these minute and particular Cares. His Physics are not disparaged or dishonoured, because he sometimes happens to be with Blacksmiths, or in a Dairy or a Kitchen. He with Dignity teaches a Countrywoman, or a Farmer's Wife, how she may with little or no Ex-pence do an Egg over with a Lay of Varnish, or put it in a little Mutton Fat, to preserve it perfectly fresh for several Months together *. I should be a thousand Times more p'eased with myself to have procured such a wholesome Food for the poor Sailors, than to have accounted for Electricity, by an Attraction which diminishes in an inverted Proportion of the Square of the Distance.

I could not, my dear Friend, better conclude this History of Experimental Physics, than by inviting you to imitate in this Study, as well as in all your Researches, the provident Cares and noble Views of Mr. *De Reaumur*. His Love for the Public (of which I am a Part) is most particularly what makes him dear to me. This Interest alone made me his Friend ; and were he born in *London*, or beyond the *Alps*, the Esteem and Gratitude I should express for his Works would be equally lively, but could never proceed from a purer Motive.

* I have experienced, that a new-laid Egg, boiled as usual, may be thus preserved without any Alteration for a Month or more ; because the white Varnish, thickened on the Pores of the Shell, hinders the Liquors from transpiring. When it is put again into boiling Water, as if it had never been done, it turns the White into Milk as well as at first. Which may be very useful for sick Persons in the Months of *December* and *January*, and at all Times in Hospitals.

THE
HISTORY
OF
Systematic Physics.

DIALOGUE VIII.

THOUGH the Hypotheses, by which *Ptolemy*, *Copernicus*, and *Tycho Brabé*, have endeavoured to account for the Motions of the Heavens, are commonly called Systems; yet this is no longer what we understand by General and Systematic Physics. We have now in Hand those Physics, which pretend to account for and explain the Original, and the inward Frame of the whole Universe. A noble Project! Four or five renowned Philosophers have busied themselves about it. They formed numerous Parties, and created many great Disputes. The History of their Pretensions may perhaps determine us to side with the better Party, or to preserve a perfect Neutrality.

Epicurus, having revived the Notions of *Leucippus* and *Democritus*, thought he had conceived very well, that Particles of Matter differently formed, after having subsisted from all Eternity, had, since a certain Time, been hooked one on another in *Vacuo*; that by moving, some in a straight Line, others indirectly, they had gathered

Epicurus's A-
toms.

thered in many different Platoons, and formed Bodies and Intelligencies: That the Liberty of Man was more especially the Work of Atoms moved in an oblique Line: That therefore, Hazard had formed the Sun, peopled the Earth, established the Order that reigns therein, and by one Mould framed both the World, and the intelligent Being who is the Spectator of it *: That we were not to think that the Sun was made to light us, or our Eye to see; but that having taken Notice that the Sun might serve to light, and our Eyes to see, we had applied the Sun and Eye to those Uses.

This sublime Philosophy was written in *Latin Verse* by *Lucretius*, commented upon by the great *Scaliger*, and by learned Men of all Countries translated into all Languages, in order to rectify the Notions of Men upon—

I provoke your Impatience in the very Beginning of this History, my dear Chevalier; and if our other Contrivers of Systems have nothing better to afford you, I perceive you are very ready to excuse me the rest: But you would very much wrong the others, by judging of them from *Epicurus*. His System is little different from those that are made at *Bedlam*; and the Inhabitants of *Abdera* did tolerable Justice to one of the first Raisers of that fine Edifice †, when they sent *Hippocrates* to him to cure his Madness.

Aristotle, and his Favourers, think the *World*. composed of primitive Matter, which has, they say, no distinct Form, and is apt to receive any Form whatever; from which sprung the four Elements, of which all Bodies are composed, and into which they are all resolved by a final Analysis.

There is indeed some Difference between that primitive Matter and the Atoms: But *Epicurus* and *Aristotle* agree in this, that they first admit of a primitive or primordial Stock of indetermined Matter, capable of entering into States and Compositions of all Sorts.

Gaffendus

* ————— *Neve putas oculorum clara. creata*
Ut videant; sed quod natum est, id procreat usum.

Lucret. de Rerum Natura.

† *Democritus.*

Gaffendus resumes *Epicurus*'s Atoms and *Vacuum*, to construct his World with: *Gaffendi's* World. With this Difference, that he puts them

into the Hand of God to make them move according to the all-wise Views of his Providence. This Philosophy never offended any body in the Point of Religion; which it does not strike at, upon any Account. But here again you are to observe the self-same Foundation of an uncertain Matter, which at first has nothing regular or determined in it, and which shall afterwards be apt to be converted into some Body or other, according as you shall think fit to handle, compose, or divide the same, and to collect it into other Masses again.

Descartes rejects the *Vacuum*, and will have every Space to be full in his World; *Descartes's* World, though it be a hard Matter to make the Liberty of Motion agree with the perfect Exactness of the *Plenum*. His Manner of conceiving the Creation of it is this. First *, God creates an immense Mass of homogeneous Matter, all the Particles of which are hard, cubical, or at least full of Angles. He afterwards imparts to these Particles a twofold Motion. He makes most of them turn on their own Centre, and several Platoons of them turn round a common Centre. And these he calls Vortices, or Whirls of Matter. This done, the whole is executed according to his Notions; and from the Friction of these Particles, worn out at their Angles, a very fine Dust will be formed, which he stiles. the first Element, or the subtle Matter; then a globular Matter, which he calls the second Element, or the Light; and at last a massy sifted Dust full of Branches, which he calls the third Element, of which all Sorts of Masses are to be made. This *Chaos* thus coming out of God's Hands, according to *Descartes*, ranks itself in Order, by Virtue of the Continuation of the two Motions thereon imprinted by God, and of itself becomes a World like ours, *in which, though God has put no Order or Proportion* †, (these are his very Words) *all the Things both general and particular, which appear in the true World, shall be perceived.*

Chemists,

* See his *Treatise of the Light, and the Principia*.

† See the *World*; or the *Treatise of Light*.

The Principles of the Chemists, in order to enable themselves to make Gold, and to prepare the Restorative which hinders us from dying, or at least considerably lengthens our Lives, were obliged to search into the Bottom of Nature; and thought they had found out, that Salt, Sulphur, and Mercury, together with a few other Ingredients, about which they are not as yet agreed, were indeed the immediate Elements of Metals, and of all Bodies; but that there was in Reality a primitive Matter, which took all Sorts of Forms, as all the Sages of *Egypt* and *Greece*, and the Philosophers of all Ages assured us there was: That consequently nothing remained to be done, but to work upon that primitive Matter, to present it with fit Moulds, and to give it a certain Turn, to have Gold, Jewels, and the *Elixir Salutis*.

Hitherto, Sir, you see a perfect Agreement among all these Sects of Philosophers as to the principal Point. They all, though under different Terms, come to a *Chaos* of primitive Matter, and of innumerable Particles which are neither Gold nor Silver, Salt or Sperm, Fruit, or any other determinate Thing, but which will serve by their Mixture to compose every Thing, and into which every Thing may at last be resolved. The only Difference I find between them, on this Account, is, that the Chemists are far more judicious than all the rest, and make a much better Use of Wisdom. The *Aristoteleans* and *Corpuscularists*, are always ready to pull one another's Eyes out, about the *Plenum* and the *Vacuum*, Matter and Form, the Principles of Bodies, and the last Term of their Decompositions; and all this to no manner of Purpose. They quarrel about the best Method of ordering Matter; as if the Question was, to create the World or to govern it. It is already made, and goes on in its Course without them. The whole Sum of their Learning does then amount to the Art of filling the Schools with Disputes, from which we reap no Benefit. Chemists go much more directly to their Point, and argue thus: According to *Aristotle*, *Epicurus*, *Gassendus*, and *Descartes*, Gold and Sand are but one and the same Matter: The great *Descartes*, by wearing out the Angles of his Cubes, saw the Sun, the Gold, and the Light itself, spring

out

out of their Dust : Let us stir up the Sand : Let us bruise the Corners and Angles of it, by the Force of Fire and repeated Frictions : Let us rob it of that accidental Form which makes it Sand ; and by giving it a certain Turn and a happy Form, let us at last bring it to be Gold. What Riches, what Helps this Metamorphosis will be to Mankind, if we can but once come at it !

If all systematical Philosophers think rightly on the Article of primitive Matter, about which they agree ; Chemists think still better in reducing all these Speculations into Practice, and in endeavouring to bring that Matter to the happy Degree, which will make them fetch Gold and Immortality out of it.

But by a Misfortune, fatal to the Glory of Philosophers, Chemists not only die, but even live not so long as other People. Most of them dry themselves up among Furnaces, and in pestilential Exhalations : But they all infallibly ruin their Fortunes. The Unprofitableness of their Attempts is a Demonstration of the Falsity of the Principle which they borrowed from the Philosophers, and dissuades us from entering into a tiresome Examination of all these imaginary Physicks. Life is too short, and we have too many Duties to discharge, to lose our Time about such frivolous Studies.

To be fully sensible of the great Mistake of Philosophers, it will be sufficient to know that they frame the World of an unformed Matter, which at first was neither Water, nor Fire, nor Metal, nor Earth, nor any Thing that we now see, and which afterwards by Motion becomes whatever we do see. Constant Experience shews them, if they are but willing to open their Eyes, that in order to procure the unfolding and growing of the transitory Species, which maintain the Scene of the World throughout all its Ages, God has prepared a Multitude of simple and uncompound Natures, which never sprung out of a primitive Matter different from themselves : That these Natures have no other immediate Cause of their Formation than God himself : That they never passed from a first State into a second : That they are as invariable as he himself is, who gave them their Being : That no Motion could ever alter or change them, or convert them into other Natures ; or, in short, resolve them

them into any Thing but what they are. They are equally indestructible and ingenerable ; and since the most violent Motion now-a days is not capable of producing any Thing in them ; they are not indebted for their special Nature to any Turn or Disposition communicated to them by Motion. Of this you will judge from a few Instances. Take some refined Gold, and put it in the brightest Fire, it will remain melted and in a State of Fusion for whole Months together. A violent Fire, which, according to the *Cartesians*, is only a violent Motion, should indeed, on this Occasion as well as in the Beginning of the World, cause some small Novelty or other in that Matter. It is certainly easier to destroy than to form. Why then cannot Motion, which fetched Gold from the primitive Matter, by its several Degrees and Variations, destroy that Gold in the Crucible, or convert it into some new Being, or at least resolve it into a small Parcel of primitive Matter ? How can Philosophers be so blind, as not to see that they mistake the methodical Notions according to which every Thing is ordered in the Schools, for Realities subsisting in Nature, while they exist only in their own Brains ? They first think of Matter in general ; then of determinate and special Matters : But must that oblige them to believe, that there is or ever was a primitive Matter ? It is admirable indeed, to look for the Analysis of Gold, and to resolve it into its Principles, in order to bring it at last to primitive Matter. They had as good analyse Flowers in the chemical Furnace, in hopes of finding, in the last Decomposition, a general Flower at the Bottom of the Recipient.

In like Manner put on a violent Fire, Sand, Mud, Mercury, or any Metal you please. The Sand shall become Glass, by the Coherency it contracts in the Fire ; and after having been whole Years together in the Glass-maker's Pot, it shall still be, and for ever remain, Glass. The Mud shall fall either into Lime or Ashes, and after the Disunion shall never be any Thing but Ashes and dead Earth. The Mercury mixed with Sulphur and all the Dregs imaginable, shall become Cinoper, or assume some other Form. It may have disappeared, but has never been destroyed or changed. It is constantly intire under these new Forms, and always the same ; and the Fire will return.

turn it to you such as it was at first. It is the same Thing with Metals. Torture them; give them whatever Motion or Alteration you may think possible by Fire, Aqua-fortis, or any other Dissolutions. They have not changed their Nature; not even a single Instant. If you put a Sheet of Iron in Aqua-fortis which has already dissolved a certain Quantity of Silver, it cannot support the Particles of both Metals at once: It returns you the Silver intirely, which sinks to the Bottom of the Vessel, and which you by Mistake thought to have been transformed into Liquor. It was only hid there, by rolling on the Globules of the Liquor, and by the Division of the metalline Particles. But these Particles are in little what they are in a Mass. The Minium or red Lead, with which they colour the Wafers for sealing Letters, is made of Lead. The Metal is no longer seen: One would be apt to think it destroyed, or to have been converted into another Nature. It is only more divided there; but its Particles never change; and if you offer such a Wafer to a burning Wax-candle, receiving the Ashes of it on a Paper; you will there see all the Particles of the Lead put in Fusion, collected into small Streams, and forming, as they grow cold, several shining Branches, easy to be discerned, even without a Microscope. - The Gold and Metals, which are extracted from the Matters where nothing metalline appears, are not formed there. They are only found in those Matters, and we extract them from those Places whither they had been carried and dispersed before. Hence the Gold found along the Rivers and in Sands: Hence the Particles of Iron, which adhere to the Knife touched with the Load-stone, with which you rake up the Ashes of Plants, or the Ashes of the Flesh and Intrails of Animals. Those metalline, saline, earthy, sandy, aqueous, fiery, and mercurial Particles, and several others equally simple, are tossed about here and there, form Masses, appear under many very different Dresses, hide, and then shew themselves again. But the Gold, the Iron, the Earth, the Water, the Sand, the Fire, the Mercury, in short, all simple and uncompounded Matters, are constantly the same both in little and large. These Natures are each of them its own respective primordial Matter: And as the most violent and most varied Motion cannot

cannot resolve them into any Thing but what they are, of course they are not, for their Structure, indebted to any Motion, either direct, oblique, or circular. All of them, as well as the whole World, came immediately out of the Hands of God himself. They are not indeed what they become by the Combinations of Motions; but what God from the Beginning was pleased they should be, to serve for the Formation of those compounded Bodies, for which his Wisdom designed them. Gold and Crystal are no longer made: They are only carried, tossed about, gathered, or dispersed. Motion therefore, which never was able to produce the least Grain of these Matters, much less was capable of producing an Earth, or its Inhabitants, or an Atmosphere, or a Sun, preserves the World, but could never adjust it: Like as the Spring of a Watch, and the Care we take to wind it up every Day, makes it move regularly, but could never construct it. It is then the Part of a considerate Naturalist, to study the Motions which maintain Nature; since they are real, regular, and constant: But attributing to the Motions imprinted on Matter the Power of forming a World, is to contemn Experience, and perhaps tacitly to revive the *Epicurean Reveries*. It is every whit as impossible for Motion to form a World, as it is evidently impossible for it to form a Grain of Iron.

If we can get nothing but Loss of Time by raking up *Gassendi's* Atoms, or in making *Descartes's* angulous Bodies whirl, we perhaps shall meet with better Success by having recourse to the attractive, centripetal, and centrifugal Power of the Northern Philosopher.

The Difference between Mr. *Descartes's* System and Mr. *Newton's* is, that the former pretends to account for every Thing; whereas the latter, modestly owning that we know not the Bottom of Nature, aims at no more than to clear a Matter of Fact, without pretending to account for the Cause of it. But as that single Fact, according to his Notions, takes in all Nature, his System does thereby become a Sort of general Physics. According to Mr. *Descartes*, that Gravity which causes Bodies to fall, is not different from the Action of those Fluids in which Planets are carried away, because every Body which is moved, and by the ambient Bodies obliged to describe a circular instead

of a straight Line, incessantly endeavours to recede from the Centre. Whence it happens, that when the Parts of the Vortex meet with Bodies that have no centrifugal Force, or that have it in a less Degree, these are forced toward the Centre ; so that the Precipitation of heavy Bodies towards the Centre, is only the Action of more active Bodies having a Tendency to avoid it.

Sir Isaac first thinks, as well as Mr. Descartes from whom he had learned it, that any Body will continue in its State of Repose or of Motion, till some new Force takes it, or causes it to deviate from that State.

Sir Isaac, in the second Place, thinks he has observed throughout all Nature (and this is the distinctive Point of his System) that all Bodies are attracted towards each other, in Proportion to their Distance, and respective Masses : That they tend towards, and gravitate or weigh upon each other. That the Sun tends towards the Earth, and the Earth towards the Sun ; but that the latter being incomparably bigger, the Approach of the Earth only towards the Sun is perceived : That likewise the Earth tends towards the Stone which was separated from it by Projection, as the Stone reciprocally tends towards the Earth : Or rather, that the Stone attracts the Earth towards itself, as the Earth attracts the Stone ; but that the Earth having, on account of its Bulk or Mass, an attractive Power infinitely greater than that of a small Stone, it thence happens, that the Earth quits not its Place, and it is the Stone that comes towards it, or is dragged away, by the attractive Power which the Earth exerts on it.

This mutual Action, which Sir Isaac thinks he perceives between one Body and another throughout all Nature, he calls *Attraction*, and proposes it as an Effect which is found all over the Universe, without being able to assign any other Cause for it but the Will of God, who appointed it to regulate the Universe. Therefore the Earth now moved round the Sun (were it only moved, not attracted towards it) would recede infinitely from it. The Moon, did it obey without any Obstacle the Law of the Motion which carries it away, would avoid and shun the Earth, and at last disappear. Likewise, if the Earth did only obey the Law of Attraction, that is, the Law whereby the Sun attracts the Earth to itself, it would draw near, and

and precipitately rush upon the Sun. The Moon, being merely attracted, would fall upon the Earth. But if the Earth, being moved and thrown far from the Sun, is at the same Time attracted by it; instead of receding from it in a straight Line, that Line will be curved by the Attraction which brings it again towards the Sun. Being always influenced by two Powers, one of which it draws from, and the other attracts it towards the Sun, it describes round the latter a curve Line, which Sir *Isaac* demonstrates to be necessarily elliptic, or something oval. The Moon likewise, yielding to the Force which makes it fly off from the Earth, and at the same Time to the Power which attracts it towards the Globe, circulates round the Earth. The centrifugal and the centripetal Force are mutually curbed by each other; and the Moon, instead of being hurried away from us by the first Power, or precipitated to our Earth by the second, is, by the Impression of both at once, retained within its Orbit.

Sir *Isaac* examines afterwards, what should be the Measure of the Motion of the Moon beginning to fall on the Earth from the Top of its Orbit, after having lost its centrifugal Force, and having, as it were, been given over to the whole attractive Force which the Earth exerts upon it. The Distance of the Moon from the Earth is known: We know likewise the Time of its Revolution: We therefore may know, what is the Portion of that Orbit for one single Minute. Geometry informs us, what Space the Moon would go through in a straight Line, falling towards the Earth by Virtue of that Force which makes it pass over that Arch or Segment of its Orbit. Having afterwards proved, that Attraction diminishes in Proportion as the Square * of the Distance increases; Sir *Isaac Newton*, by his Calculations, finds that the Moon, falling from the Place where it now is, would first go through fifteen Feet in one Minute; and that near the Earth it would, by Virtue of the same Law, in one

* A Square is any Number multiplied by itself. If the Interval from the Earth to the Moon be divided into three Stratas; the *Stratum 1*, has for its Square 1. The *Stratum 2*, has for its Square 4; and the *Stratum 3*, has for its Square 9. The Attraction, which diminishes in Proportion as the Square of the Distance increases, shall then act as 9 in the first *Stratum*, as 4 in the second, and as 1 in the third.

one Minute go through a Space of three thousand and six hundred Times fifteen Feet. Having at last examined the Spaces which a Mass of Wood or Stone goes through near the Earth, when let fall upon it ; he concludes, from what Experience shews of the Fall of Bodies, that a Stone in the Neighbourhood of our Globe would in one Minute go through a Space of three thousand and six hundred Times fifteen Feet. The Moon, let go from its Orbit, would then obey the same Law which precipitates the Stone. By a necessary Consequence, if the Stone was carried as far as the Orbit of the Moon, and thence let fall on the Earth, it would go through a Space of fifteen Feet there. Attraction is then the same Thing as Weight.

Mr. *Privat de Molières*, a Member of the *Academy of Sciences*, has in his *Physical Instructions* preserved the Grounds of Sir *Isaac's* Observations. He admits of all the Proofs which shew that the same Cause, which makes a Stone to gravitate on the Earth, makes the Earth gravitate upon the Sun, and the Moon upon the Earth. But he ascribes that Effect to a Cause very different from that imagined by Sir *Isaac*. The *French* Philosopher, while he admires the Exactness of the geometrical System of the learned *Englishman*, at the same Time thinks it inconsistent with the whole Plan of Nature. He is shocked by a Principle which makes our World a Whole, whose Parts are more loose and incoherent than those of a Skeleton. All the Notions we have of Mechanics, seemed to him quite demolished by his ideal Attraction ; which, according to the Favourers of the *English* Geometry, is reciprocally exercised among Bodies separated by an immense Vacuum, and which makes them revolve in nothing, without uniting them by any intermediate Bond. Mr. *De Molières* resumes Mr. *Descartes's* Vortex, whose Existence appears to him almost palpable in Nature. He mends that whole System, and by concluding, from the very Structure of the Vortex, all the Effects perceived by Sir *Isaac*, he in a Manner reconciles the two antagonist Schools.

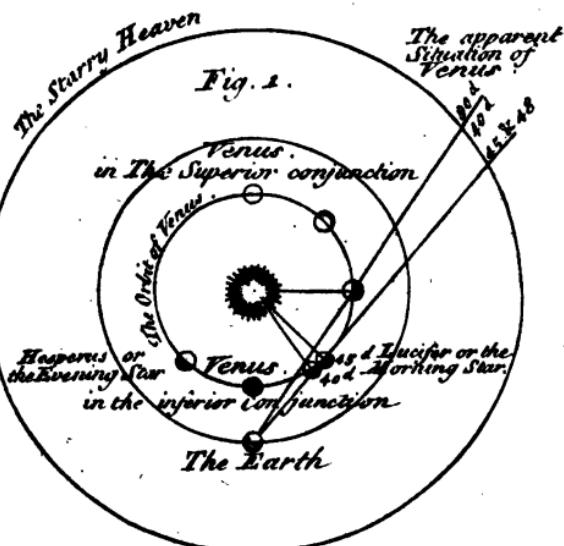
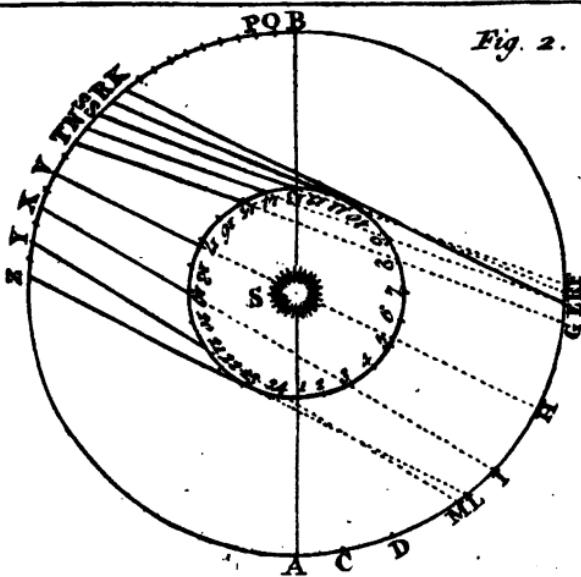
That Vortex is no longer composed, as Mr. *Descartes* thought it, of hard and inflexible Balls ; but of many small Vortices, whose Particles incessantly incline to recede from their own Centre ; while the whole tends towards receding from the common Centre. A massy Body

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Body like the Moon or the Earth, thrown into that Vortex, must needs be presently moved by it, and carried away in the Direction of the whole Vortex. But the Parts of that heavy Mass being strictly united, and at Repose one by another, of themselves make no manner of Efforts to move, and have no other Motion than the Impulsion which the whole Body of the Planet receives from the Vortex in which it swims: Whereas the Balls of the Vortex have a double Motion, and make a double Effort. They all tend towards receding from their common Centre, so soon as they are moved and forced by the ambient Vortices to move in a circular Line. Besides, all the Particles of these Balls do in little round their own Centre, what the Balls themselves do in general round their common Centre. From this double Tendency there results a double Force, which draws them from the Centre more powerfully than the Motion imprinted on the Planet draws it from the Centre of the Sphere. The Planet when thrown into the Vortex, has indeed therein received a centrifugal Force, by receiving a circular Motion; But its Parts being in Repose, it has a less centrifugal Force than the Vortex, in which this Force is double, both from the Motion of the minute Vortices which fly from the common Centre, and by the Particles of the minute Vortices which at the same Time fly from their own Centre. This Excess of centrifugal Force in the Matter of the Vortex, over and above the centrifugal Force of the Planet, must needs prevail. The Planet having a less Tendency towards receding from the Centre, than the Matter which pushed it that Way, it will thence happen that the Earth will by Degrees draw near the Sun, and the Moon fall on the Earth. In short, Mr. *De Molieres* employs but one single Action, or one same Cause, to form the centrifugal Force of the Vortex, and to make the Planets and all massy Bodies gravitate towards one and the same Centre; whereas Sir *Isaac* adds to the Motion imprinted on all these Bodies, another Power or Law, which he calls Attraction, and which inclines them all towards drawing near each other more or less swiftly, in Proportion to their Masses or Distances, while there is no need at all of this second Power, and it is impossible to conceive it.

Mr.





The Motions of the inferior Planets.

Ja. Mynde Sculp.

Mr. *De Mollières*, after having by his ingenious Explanation of Gravity, helped us to conceive the twofold centrifugal Force of the Vortices, and the re-approaching of massy Bodies towards the Centre, as a simple Effect of that Force, still leaves us in the Expectation of what he will introduce, to sustain the Planets in their Orbit, and to hinder them from falling to that Centre. But it is easy to foresee, that in the Lessons which he is now preparing for us, he will make use of many different Vortices, or at least several Atmospheres thrown round the Planets, to make them roll one upon another without falling; like Balls of different Matters, which press and flatten one another a little in rolling over each other, while the Centres, which tend towards one another by the Impulsion of the ambient Vortices, are however unable to draw near each other.

This Explanation of Mr. *De Mollières*, when applied, not to create the World, but to conceive the Motions and Preservation thereof, is the more acceptable, because it may also be of Use in the particular Explication of a Multitude of Phænomena, and of particular Cases. Such are, for Instance, the Flux and Reflux of the Sea by the Pressure of the Sphere of the Moon on that of the Earth; the disordering of the Satellites of *Jupiter*, by the Pressure of the Sphere of *Saturn* on *Jupiter's*; the Attractions and Repulsions of electric Bodies, by the small Atmospheres, which they acquire or lose, as they are touched one Way or another; the chemical Dissolutions and Fermentations, by the Diversity of the Forces of the small Vortices which compose the Liquors, and which can never appear at Rest, but when they have put themselves in Equilibrio after a long Agitation, occasioned by the Inequality of the Efforts.

I shall take Care here not to enter upon a particular Account of the Systems imagined on Gravity by M^s. *Huygens*, *Bulfinger*, *Bernouilly*, and many others. This is only a single Point of the Mechanicks of the Universe. Ask the Explication of it from fifty Naturalists, they all will think they have given you a Scheme of Physicks, the more valuable in Proportion as they shall use more Calculations and Geometry in them. But the Distance between

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between Arithmetick, and Geometry, and Physicks, is often very great. All these indefatigable Calculists, and even often setting out from the same Point, will lead you to very different Sums, to very different Mechanisms, and to as many Systems as there are Heads. What will then happen, when from this Point we would pass on to the Explication of the Mechanism and intimate Structure of the other Parts of the Universe? Entering into these systematical Opinions, would be quitting the *Spectacle de la Nature*, and losing Sight of the certain Use we may make of it; in which our true Physicks consist. Another Reason, which ought to make us entertain a Jealousy of Systems, is, that though they should appear ever so grand at first Sight, the Applications we make of them to particular Effects, most commonly prove abortive and ridiculous. For Instance: Make use of the System of Attraction to explain the Phænomenon of the Load-stone, where, it seems, it should be of very great Use; or to explain Electricity, or to account for what they call Fermentation; you will find that the Principle will fail you every where, and give you Intelligence of nothing. One is soon obliged to vary the Attractions as well as the Effects. Here you have an Attraction, which operates in the whole Depth of the Mass; there you have another Attraction, which operates only through the slightest Surface of Bodies. There is a certain Attraction which is constantly the same, whether the Bodies be thick or thin, while another Attraction varies according to their Bulk, or Thickness. The Attractionists were chiefly in love with that which they saw, or fancied they saw, in electric Bodies. It could not be mistaken; and it operated exactly as in the Planets, diminishing round about as the Distance increased. By Misfortune, an experimental Philosopher came and overthrew all this ideal Building; and by fastening a small wooden Ball at the Extremity of a Cord eleven or twelve hundred Feet long, he has found, that if we should present an electrical Tube to the Middle, or even the Beginning of that long Cord, the small Particles of Gold placed at the other Extremity under the wooden Ball, would apply themselves; and as quickly fasten to it, as if the Electricity had acted at a Foot distance from the Table.

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Tube. One of our most learned *Newtonians* * has made a thousand Experiments upon the Load-stone; and after infinite Cautions and Calculations, he frankly owns, that Attraction failed him when he wanted it, and that he could understand nothing in it.

I shall, my dear Chevalier, here conclude this History of my Systematical Physics, as there is no Necessity for the present of my giving you a more extensive Account of it. It will always be Time enough to resume these sublime, and but little necessary Speculations. It would even be dangerous at your Age, and perhaps at any other, to prepossess you with any particular System; to which you infallibly would, either willingly, or whether you would or not, make every Phænomenon to refer: Which is an infinite Disadvantage to the Progre. of true Physics; either because you never get out of the Circle of some certain Généralities, or because you see every Thing merely according to your own Prejudices. This then brings you back again to Experimental Physics. It is indeed the only Philosophy that ever was of any Use to Mankind; and I have already shewed you, that these Benefits were without Number. But could you ever, in pursuing the Study of Physics, follow a wiser or more judicious Method than that which *Mess. de l'Academie des Sciences* always followed in teaching it us? They never approved in a Body of any general System. They are convinced, that if Man can any Way be allowed to arrive at the intimate Knowledge of Nature, he cannot obtain it otherwise than by a long Series of Experiments and Facts for many Years together; and that if, on the contrary, that perfect Knowledge of Nature is for ever interdicted to our present State and Condition, at least the Experiments and the Knowledge of Particulars will not fail, as we daily experience, to procure many real Services to Mankind. This infinitely judicious Principle, which has been a standing Rule to them, and the Nature of the several Functions which these learned Men have divided among themselves, are exactly and equally grounded on our Wants, and the Measure of our Capacity. Nay, more: Experimental

Q 2

Physics,

* *Mr. Muschenbroeck.*

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Physics, to which they procured a vast Credit, is the only useful System, because it is the only one agreeable to our Condition, which we may, without any Risk, call the System of Providence.

An Experience of six thousand Years is fully sufficient to inform us of what is either accessible, or interdicted to us. So long as Man, in his Researches, has busied himself about what is submitted to his Government, his Efforts were always rewarded with new Discoveries: But whilst he presumed to dive into the intimate Structure of the several Parts of the Universe, which he was not appointed to put in Motion, his Ideas were never any Thing but an odd Medley of Fancies and Uncertainties. If he studies the Measures of Quantities and the Laws of Motion, not indeed to fathom the Heavens, or to weigh in a Balance the Masses of the celestial Bodies, but to know the Order of his Days: If he observes the Relations which the Aspects of the Heaven have with regard to his Habitation, and the Progress of the Light through the Mediums he offers thereto; the Helps which he may find from the Equilibrium of Liquors, or from the Weight and Celerity of the Bodies he is Master of, or from all the other Experiments that fall under the Eye, and especially under his Hand; in short, if he applies Experiments to the Necessaries of Life, this will be a System of Physics full of Certainty, and productive of great Advantages. It is then these Subjects which I hope to make the Matter of the Conversations I shall hereafter prepare for you. But undertaking to determine what it is that regulates the Motion of the Universe, and to penetrate into the general and particular Structure of the Pieces of which it is composed, is renouncing the Glory of improving and making our Dominion prosper, to run after empty Hopes: It is abandoning Treasures which lie open to us, and obstinately knocking at a Door which has been for these six thousand Years shut to us.

It is no conjectural Opinion, but a palpable and experimental Truth, that God gave us a very great Facility of conceiving all those Things which we are to manage; and has, on the contrary, concealed from us the Knowledge of those Things which he himself puts

in Motion, without trusting the Government of them to our Care. Thus, for Instance, we know not the Structure of our Stomach, because God has freed us from the Care of digesting. Let the greatest of Anatomists do his utmost to have the Management of his own Digestion; all goes very often contrary to his Intentions. On the other Hand, we have in our Senses so many attentive and faithful Monitors, that inform us in due Time what Foods may be useful to us. Why then have we so many Means of knowing our Foods, unless we are charged with the Care of looking out for, and of chusing them? And why, on the contrary, are we ignorant how we digest, if not because God's Will has evidently been, that the Digestion should be performed within us without our Participation? God, by sparing us that Trouble, spared us also the Knowledge of the Mechanism, which constructs the several Kinds of Flesh or Fruit we eat; and of the Mechanism, which extracts from them all the Juices which nourish us. This Knowledge would have been only fit to give us great Distraction. We arrive at the Age of Four-score without knowing what Digestion, or the Mechanism or Motion of the Muscles are. We are served without any requisite Care of our own. Had we known the particular Structure of the Stomach, we should have desired to regulate the Functions of it. God did not grant to Man this Knowledge, because he made him not merely to digest. Digestion is brought about without him, and God designs him for other Employments. If he denies him the Knowledge of the Mechanism of his Stomach, for fear of multiplying his Cares, is it to be supposed that he will grant him the Knowledge of the Structure of the World, the Motions of which he did not appoint him to regulate?

I don't know whether our modern Philosophers have rightly entered into the Plan of the Creator, when they set a less Value on the Knowledge which our Senses procure for us, than on that which they think they derive from a profound Meditation. A single Instance will explain what I mean.

The rough Sailor knows nothing of the Load-stone but what his Senses testify of it. He knows the constant Di-

rection of it towards the North ; and there ends all his Learning. The Philosopher endeavours to know the Cause of that Phænomenon : In order to which he employs the Pores in a spiral Line, the Attractions and Repulsions ; and after he has for several Years together employed his Mechanics, Geometry, and Calculations about it, he either is forced to own that he himself understands nothing of what he says, or has the Mortification of not being able to make others come into his System. The Systematical Philosopher, who thinks himself ignorant of every Thing he knows not the Cause of, spends his whole Life in hunting after probable Reasons, and remains locked up in a Closet, where he is of no Use to the rest of Mankind. The Sailor makes use of what his Senses teach him of the Direction of the Load-stone towards the North, and with that Help goes round the World. Chuse, if you will, ten thousand other Instances of effectual Knowledge, and you will find, that there are very few that are not of Use to us. They cannot increase without our becoming richer. But do we look for the Causes of these Effects ? We find nothing but Unaptitude and Uncertainty. Who, after this, cannot discern the Intention of God, in the Measure of Knowledge which he for the present grants to our Understanding ?

It is a palpable Truth, that our whole Knowledge is only concerning particular Things. The Subjects of it are dispersed around us, on the Earth, and in the Heavens. God, together with Eyes and Understanding, has endowed us with a Measure of Curiosity, which makes us wander from one Object to another, that new Experiments may enable us to procure our Brethren new Conveniences, and that whatever is upon the Earth may by Degrees be rendered beneficial to Mankind. But if Man can on Foot go from Brest to Pekin, it does not follow that he will ever reach to the Moon ; and though he has in his Hands such a Principle of Strength, as enables him to sustain in the Air whole Piles of Oak-timber, and the largest rough Pieces of Marble, he will not offer his Levers to the Moon to make it jump out of its Orbit, or grapple Jupiter with his Hooks, in order to rob him of one of his Satellites.

His

The Motions
of the Superior Planets.

S R X Q P O N

Heaven.

M

The Starry

The Orbit

of Jupiter.

11 10 9 8 7 6 5 4 3 2 1

Fig. 3.



Ja. Mynde Sculp.



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His Knowledge is limited as well as his Strength, and these Bounds and his Wants are but one and the same Thing. He is barred every where, when he rushes into empty Speculations: But he constantly goes from one Discovery to another; and these Discoveries produce Wonders, when he busies himself about improving what is round him. Our Reason always employs itself with Success, when it strives to render experimental Truth useful to us: When it prudently makes use of God's Favours, and praises him for it. This is the whole Sum of Man's Knowledge.

A N
EXPLICATION
 O F T H E
Motion of the PLANETS
 I N T H E
COPERNICAN HYPOTHESIS.

THERE are six Planets of the first Class, which turn immediately round the Sun, *viz.* *Mercury*, which makes his Revolution in three Months; *Venus*, which makes her's in seven Months and a Half, or thereabouts; the Earth, which, as it is much more remote, describes her Orbit in 365 Days and a Quarter; then successively, and at still greater Distances, *Mars*, which perfects his Revolution in 686 Days; *Jupiter* in 4333, that is, in about twelve Years; and *Saturn* in 10759 Days, or in about thirty Years. There are five Planets of the second Order, or which have a large Planet for the Centre of their Revolution, and are inseparable from it; such is the Moon, with the Earth for her Centre: Such are also the four Stars of *Medicis* (now the four *Satellites*) which turn at different Distances round *Jupiter*. Since Galileo's Time, five small Moons have also been perceived revolving round *Saturn*; which makes in all ten secondary Planets. If we were placed in the Sun, that is, in the fixed Centre of the Revolution of the six greater Planets, we should see them revolve round us in an uniform Manner, and advancing from West to East according to the Succession of the Signs. We should see them always in their Full; that

that is, always turning their enlightened Half towards us. But as we see them from our Earth, which has a Course peculiar to itself, while they have others of their own, there thence results a great Variety of Effects and Situations, which introduce Inequalities, and the Appearances of Oddness in a Motion perfectly simple and uniform. Besides, the Earth being more remote from the Sun than *Venus* and *Mercury* are, and at the same Time much less distant from the Sun than *Mars*, *Jupiter*, and *Saturn*; this Diversity of Remoteness still causes such Appearances as are not the same in the superior, as in the inferior Planets. *Mars*, *Jupiter*, and *Saturn*, are called the *Superior*, because their Orbits are above ours, and inclose it. *Mercury* and *Venus* are called the *Inferior*, because the great Circle of the annual Revolution of the Earth, incloses the Circle of the Revolution of *Venus*, and the Orbit of *Venus* takes in the Circle of the Revolution of *Mercury*, which is the Planet nearest the Sun.

The apparent Motions of VENUS and MERCURY.

THE Circles which *Mercury* and *Venus* describe in going from West to East, are not in the Plane of the Ecliptic, or of the Line which the Earth describes in revolving in one Year round the Sun. But the Circles of *Mercury* and *Venus* cut the terrestrial Orbit in two opposite Points, called *Nodes*, like Hoops set into one another, and one of which crosses and touches the other in two Points only. The Orbit of *Mercury* makes an Angle of about seven Degrees with the terrestrial Orbit; and that of *Venus* makes on each Side an Angle of three Degrees and 24 Minutes with the same Plane. If we should see *Mercury* and *Venus* from the Sun, they would either be in the Line which passes through the *Nodes* and the Sun (in which Case they would be seen in the Plane of the Ecliptic, in which the one might be eclipsed by the other) or they would be seen out of the Line of the Node, that is, sometimes more, sometimes less elevated on that Plane. None of the Planets, whether primary or secondary, in its greatest Elevation above that Plane, deviates from it more than ten Degrees. If therefore we take in the Heavens a Distance of nine or ten Degrees on each Side the Ecliptic, we shall have a Breadth of

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18 or 20 Degrees to inclose all the Declinations of the Planets. This is that large Band which we call the *Zodiac*: And the several Deviations and Re-approachings of the Planets, with regard to the Plane of the Ecliptic, are the only Variations that would be perceived in their Motions observed from the Globe of the Sun. But it is quite otherwise seen from the Earth. Let us remark what the Appearances of the two inferior Planets will there be.

1. *Mercury* and *Venus* must appear in the Plane of the terrestrial Orbit, when they are in the Node; and these two Planets afterwards must recede from the Plane of the Ecliptic, as they deviate from the Nodes. But the Distance from these Planets to the Plane of the Ecliptic, even when they are in the same Part of their Circle, must needs appear sometimes greater, sometimes less, according as the Earth is near to, or remote from them. For it is a Law in Optics sufficiently known, that the more remote the Eye is from the Object perceived, the smaller the Angle is which the said Object seems to make with a Plane, or with another Object; and on the contrary, the nearer the Eye is, the greater is the Angle under which it sees the Object.

2. *Mercury* and *Venus*, seen from the Earth, do not appear equally enlightened. They are seen with a Crescent sometimes increasing, sometimes decreasing. They are seen with one whole Half sloped off, or under the Form of a Quarter; sometimes full, and at last totally darkened or eclipsed.

The two Conjunctions. When *Mercury* and *Venus*, receding from the Earth as far as they can, get behind the Sun, and to it, as well as to us, oppose their whole enlightened Half, that Situation is not called Opposition. This Term is reserved to express the Situation of the superior Planets, when the Earth is just between them and the Sun. But this Passage of the two inferior Planets behind the Sun, is called their *superior Conjunction*. It is called Conjunction, because these Planets seem then to draw near the Sun, and to lose themselves in his Rays. It is called the superior Conjunction, because the Approach is made on the other Side of the Sun, and in order to distinguish it from that which is made under the Sun, when the Planet, in revolving round the Star, places

places itself between the Sun and the Earth. The second Reunion is called the *inferior Conjunction*. The Planet in the superior Conjunction is not indeed eclipsed, but drowned by the superior Splendor of the Sun; and when it comes near the Line of the Nodes, it may in Reality be eclipsed, by actually passing behind the Body of the Sun. The Planet in the inferior Conjunction seems again eclipsed, because it is lost in the Rays of the Sun, and because it turns its whole dark Half towards us. But instead of being really eclipsed by the Interpositions of some solid Body, it itself eclipses that Point of the Sun over-against which we may perceive it by the Help of the Telescope. It forms a Spot, which proceeds from the Eastern to the Western Limb of the Sun. The Planet afterwards leaves it, in order to repass behind it, following the Succession of the Signs from West to East. A few Days before the superior Conjunction, and some Days after, *Mercury* and *Venus* turn towards the Earth nearly their whole enlightened Half: They must of course be seen in their Full. But as they are then much more remote from the Earth than in the Approach of their inferior Conjunction, since they are withdrawn from it by the greatest Part of their Orbit, they, notwithstanding their being at full, must needs appear less brilliant, and more and more diminished by the Neighbourhood of the Sun.

A few Days before the inferior Conjunction, and some Days after, they turn almost their whole darkened Half towards the Earth. We therefore perceive but a very small Edge of the enlightened Half, and the Crescent must needs appear very dim, unless it begins to recede pretty much from the Sun, as it draws the Quarter: And it is then that *Mercury* may be seen plainly, and that *Venus* casts a far more brilliant Light than the Splendor of the full Moon. *Venus* is never brighter than when it is, not indeed in its Quadrature, that is, at 90 Degrees from its inferior Conjunction, but at 40 Degrees and little more. The Reason of this Difference is, that *Venus* at 90 Degrees from her Conjunction seems to be near the Sun, and is thereby more weakened than at 40 Degrees and something more. For *Venus*, as well as any other Planet, is perceived in the Point of the Heaven that terminates the Line which is supposed to pass from the Earth through the Planet up to

the starry Heaven. Now the Line, which passes through *Venus* at the Distance of 40 Degrees and a little more from the Sun, terminates at a Point of the Heaven, which appears more distant from the Sun than the Point where the Line, drawn from the Letter T, to *Venus* in the Quadrature of his Revolution, or at 90 Degrees from her Conjunction, does terminate. For any Line, that touches the Circle without cutting it, deviates more from the Extremity of the Line that crosses the Centre, than any other Line that cuts the Circle. Now the Line drawn from the Earth to *Venus*, being at 40 Degrees from her Conjunction, touches the Circle of the Revolution; whereas the Line drawn from the Earth to *Venus* in her Quadrature, or at 90 Degrees, cuts and slopes away the Circle. The Extremity of that Line does then begin to draw again near the Extremity of that which passes through the Centre, that is, near that Point of the Heaven where the Sun is seen. *Venus*, when she is between 40 and 48 Degrees distant from the Sun, must be more brilliant or less drowned than at 90; and as she leaves not the Circle of her Revolution, the Degree 40 is at the same Time the Place where it shines most, and that at which she begins to be in her greatest Remoteness from the Sun. It is the same with *Mercury* at 30 Degrees from the inferior Conjunction. For a little after these Points, they both begin to draw near the Sun again, in Appearance I mean, and only with regard to the Point of the Heaven under which we see the Sun; since they, in Reality, always keep in an uniform Situation with regard to that Star; unless they, instead of a circular, describe an oval Line round it; which, however, alters nothing in our Explication, and is not the Object we must here employ our Thoughts upon *.

When *Mercury* and *Venus* have passed the superior Conjunction, they from the Earth are seen advancing according to the Order of the Signs; that is, from West to East. It must therefore hence happen, that our Horizon, turning with the Earth from West to East, meets with the Sun sooner than with these two Planets. They in this Case, therefore, will rise only after the Sun, and will not be seen in the Morning, because the Light of the Sun will drown them. But they will appear in the Evening

* See the Figure 1, subjoined.

lag after Sun-set, because the Sun being then hidden below the Horizon, they at that Time may be sufficiently remote from him to be seen towards the West. Therefore *Mercury* and *Venus* will be seen in the Evening only, from the superior Conjunction to the Approach of the inferior. Then it is that *Venus* is called *Hesperus*, *Vesper*, or the Evening Star. Her Brightness increases together with her Remoteness from the Sun, and afterwards decreases in Proportion as she draws near him again. It is the same with *Mercury*, which can hardly be perceived but at its greatest Distance from the Sun, which is 30 Degrees.

When *Mercury* and *Venus* are near the inferior Conjunction, their Brightness diminishes. In the inferior as well as in the superior, they set and rise with the Sun, which drowns them for several Days together. When passed the inferior Conjunction, they will recede from the Sun by a Motion which will appear quite contrary to that by which they have been seen receding from the Sun in the superior Conjunction. They at that Time went according to the Succession of the Signs. Going down between the Sun and the Earth, and then receding from the Sun, they seem to go contrary to that Order, *viz.* from East to West. By this Means becoming more Westward, with regard to us, than the Sun, to the Right of which they at that Time are; our Horizon, by turning with the Earth from West to East, shall meet with them sooner than with the Sun. We therefore shall see them rising in the Morning before Dawn, and their Elevation above our Horizon will appear greater in Proportion before the rising of the Sun, as they shall be more distant from that Star. Thea *Venus* goes by the Name of *Lucifer*, or the Morning Star. *Mercury* and *Venus* will afterwards again draw near the Sun in the superior Conjunction.

A Figure will presently make us sensible why *Mercury* and *Venus*, though revolving in an uniform Manner round their Orbit, yet appear to us sometimes direct, or going according to the Succession of the Signs, sometimes stationary, or remaining awhile in the same Points of the Heaven; and sometimes retrograde, or going contrary to the Order of the Signs. What we are going to say of *Mercury*, is a sufficient Hint of what happens also to *Venus*.

Let

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Let the great Circle A, B, be the terrestrial Orbit, and the small Circle 1, 13, be the Orbit of *Mercury*, which may be supposed to be pretty near concentric at the Point S, that marks out the Sun. The Distance from *Mercury* to the Sun is two-fifths of that of the Earth from the Sun. The Radius of the small Circle 1, 13, being to the Radius of the terrestrial Orbit A, B, as 2 is to 5; we have the just Representation of the Orbits of *Mercury* and the Earth. On the other Hand, it is known that *Mercury* makes his Revolution in about three Months, and the Earth in twelve. Therefore the periodical Time of *Mercury* is only the fourth Part of the annual Revolution of the Earth.

Let us suppose *Mercury* to be in the Point of his Revolution marked 1, and the Earth in the Point B; it is plain that in this Situation *Mercury*, with regard to the Earth, is in its superior Conjunction; and if *Mercury* could then be perceived for the great Light of the Sun, we should see this Planet in the Point of the starry Heaven marked A, it being the Point to which the Observer must refer it. If on the terrestrial Orbit you take the Ark B, S S, *viz.* the Half-quarter, or eighth Part of the Whole, it is evident that *Mercury*, which describes its intire Orbit while the Earth describes but one quarter Part of her own, will go no farther than from 1 to 13, or only make half its Revolution, whilst the Earth shall go from B, to S S, or make one Half-quarter of her Revolution. Let us divide the Ark B, S S, into 12 equal Portions, and the Semicircle 1, 13, likewise into 12 equal Portions. *Mercury* will make one twelfth of its half Revolution, whilst the Earth will make one twelfth of the Half-quarter of her own. Whilst the Earth is going from B to O, we shall see *Mercury* passing from 1 to 2, and the Eye of the Spectator will suppose the Planet to go from the Point A of the starry Heaven, to the Point C. Then passing from O to P, the Earth will see the Planet *Mercury* arrive at 3; and will refer it to the Point of the Heaven D, and so on. The Planet in this Case will be direct, because it will appear to do what it in Reality does, *viz.* to go according to the Order of the Signs A, C, D, &c.

When

When the Earth shall describe the Ark K, S S, *Mercury* going on his Part from the Point 11, to the Points 12 and 13, will appear to make only the Ark E F, whereas when the Planet was in A, it had in equal Time described the Ark A, D, much larger than E F. Of Course its Motion must then needs appear much slower. It is from K to S S, that it appears in its greatest Remoteness from the Sun, and the Lines drawn from the Earth to the Planet cut the least of any upon the Circle of the Revolutions of the Earth.

Whilst the Earth describes the Ark S S, N, T, which is equal to two Portions of another Half-quarter of her Orbit, and while *Mercury* describes the Ark 13, 14, 15, which is two Portions of its other Half, this Planet will be seen with the parallel Rays S S F, N E, T G. Now it is a Rule in Optics, that when a very remote Object is seen by several Radii parallel among themselves, it seems to be at rest, though it be really in Motion; and it is referred to a Point of the Heaven where it seems to be motionless; because those parallel Radii, under which it appears at several Times, though very distant from each other, are relative to two different Points of the Heaven, which on account of their amazing and prodigious Remoteness, with regard to us, are confounded into a single one. The Planet must in this Case then appear motionless or stationary.

By this we see, that the Planet *Mercury* has had a direct Motion from A to E or F, and that the Time of his being direct has been much longer than that in which he was stationary. When afterwards the Earth shall describe the Ark T, V, X, or four Portions of her Half-quarter, and *Mercury* the Ark 15, 19, or four Portions of this Half, this Planet will successively be seen in the Points G, H, I. Now this Motion is contrary to the foregoing Direction. It will then appear retrograde, and going contrary to the Order of the Signs, or from East to West. Being at the Point I, its Swiftness will diminish, and being again seen according to the Lines XI, YM, which are parallel among themselves, the Eye will refer it to the same Point of the Heaven, the Interval of these two Lines vanishing, so that they seem to touch one another. *Mercury* will then a second Time appear stationary. The Earth afterwards going

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ing from Y to Z, the Planet which shall then be in the Points 23 and 24, will in the Starry Heaven correspond with the Point L, and again will begin to appear direct. It is likewise plain, that the Ark of Retrogradation G I, or F M, is less than the Ark of Direction A G or A F, and on the contrary, that the Ark of Retrogradation is greater than that of the Station F G, or I, M.

The Motions and Appearances of the superior Planets.

Fig. 3. **T**H O U G H the superior Planets, like the inferior, advance with a direct and uniform Motion in their own Orbit, yet they as well as the inferior, have several Appearances of Irregularity, grounded on the Concurrence of the Motion and Situations of the Earth with the Aspects of these Planets. The Instance of what is observed in *Jupiter* will sufficiently illustrate the Inequality of the Aspects of the other two.

The Distances of *Jupiter* and the Earth with regard to the Sun, are between themselves as 26 is to 5; that is, if we conceive the Earth to be distant from the Sun 5 Measures, each of them of a certain Number of Leagues, the Distance of *Jupiter* from the Sun shall be 26 of the like Measures. If therefore you describe Circumferences with such Radii as may, when compared together, be between themselves as 26 is to 5, these Circumferences will represent those, which the Earth and *Jupiter* describe round the Sun. The Earth is a Year in compleating her Orbit. *Jupiter* compleats his in 12 Years. The twenty fourth Part of a Circle is the Half of one twelfth Part: If then we take the Ark T V, being the 24th Part of the Orbit of *Jupiter*, this Planet shall describe the Ark T V, the Half of the twelfth Part of the Whole, while the Earth shall describe A B, D, G, the Half of her intire Orbit. Let us divide the Ark T V, and the Semicircle A B, D, G, into the same Number of Parts respectively equal; for Instance, into 6; we shall be sure that *Jupiter* will describe one sixth Part of the Portion T V, while the Earth describes one sixth Part of the Ark A B, D, G. By this Means we shall have the principal Places where the Earth and *Jupiter* shall meet together. Let us suppose the Earth to be in A, and *Jupiter* in Conjunction behind the Sun S in T: If *Jupiter* can at that Time be seen, we shall refer it to the Point

Point M of the starry Heaven corresponding with it. While the Earth shall describe the Arks A, B, C, D, *Jupiter* shall describe 1, 2, 3, 4, and the Eye will successively perceive him in the Points M, N, O, P, of the starry Heaven. The Distance is greater from M to N, than that from N to O, and the Ark N O is greater than the Ark O P. Therefore, though *Jupiter* has an equal Motion in his Orbit, we see him move with a Celerity which insensibly diminishes. The Earth going from the Point D to the Point E, *Jupiter* will go from 4 to 5, and will appear to proceed from P to X, a Portion of Circle still less than was the foregoing. Its Swiftness will then appear to diminish more and more. The Earth afterwards will describe the Ark E F, and *Jupiter* 5, 6: But the Lines E 5 X and F 6 R, according to which the Earth sees *Jupiter*, are parallel; therefore the Eye will refer them to the same Place of the Firmament, and the Planet will appear motionless and stationary. If afterwards the Earth describe the Arks F G H I, *Jupiter* will at the same Time describe the three Arks 6, 7, 7, 8, 8, 9. But, as the Line I 9 Q, according to which the Earth sees *Jupiter*, cuts the Parallels E X, F R; the Point Q, to which the Eye refers *Jupiter* in the starry Heaven, will be on the Right-hand of the Points R, X, where *Jupiter* was seen during his being stationary. The Planet will then appear more Westward and retrograde. The Earth shall afterwards go from I to K, and *Jupiter* from 9 to 10, which will produce parallel Lines, and a second Time make *Jupiter* stationary. Finally, the Earth passing from K to L, will see *Jupiter* going from 10 to 11, and answering to the Point S of the starry Heaven, so that the Planet shall seem to advance from West to East, and again shall become direct. If we know in the same Manner, the periodical Times of *Mars* and *Saturn*, we may, by the Rule of *Kepler*, determine the Distances of them, and then with equal Facility express their Situation. But these Variations are altogether inconceivable in any other Hypothesis than that of *Copernicus*.

A N
E X P L A N A T I O N
 Of a few
F I G U R E S.

THE Frontispiece represents *Galileo* making on the Tower of St. *Mark*, and in Presence of several *Venetian* Noblemen, a Trial of the Telescopes he had constructed upon the Recital of the Effects of the Spying-glass newly invented in *Holland*. See *Il Teatro d'Uomini Letterati*. Art. of *Gal.* and *Dialogue VI.* of *Part II.* of *this Vol.*

P A G E 31.

The CREPUSCLE, or Twilight.

The inner Circle represents the Globe of the Earth. The outward represents the thicker Air, or the lower Region of the Atmosphere, which incompasses the Earth immediately.

The Space contained between the two Circles may be called the Atmosphere, which probably is the inferior Part of a Vortex of Ether, or of very fluid and very extensive Matter, in which the Earth is carried away. The Vortex of the Moon revolves towards the Extremities of ours, and both, very likely, are pressed sometimes more, sometimes less, by the Spheres of the neighbouring Planets. It will be

be sufficient for the understanding the rest of the Figure, to observe, that when the Light enters from a clearer Element, such as the Ether or the pure Air, into a dense and gross Element, as is the grosser Air, it bends and enters into it, inclining a small Matter towards the perpendicular Line, which may be imagined from the Surface of the Fluid to the Centre. A H represents the Horizon with regard to the Eye placed in A.

S, the Sun at one Degree under the Horizon; S, C, a Ray meeting the Atmosphere at the Point C, and which, in entering it, is bent and deviates from its direct Way, drawing nearer the Perpendicular C T, so that the Ray being broken, is, by this bending, confounded with the horizontal Line H A, and causes the Sun to appear to be already above the Horizon, though it is as yet under it.

S S, the Sun 18 Degrees under the Horizon. The Ray S S, E, falls upon the Atmosphere at the Point E, and instead of continuing its Way directly towards e, it is bent, and enters into the thicker Air a small Matter. This Ray, after having bent at E, goes directly to C, where the Horizontal Line cuts the Atmosphere. There the Ray E C is partly lost in the Heaven, partly reflected upon the Bottom of the Atmosphere, and faintly brought again towards the Eye in A. The reflected Ray C A making the Angle of Reflexion B C A, equal to the Angle of Incidence E C F, this Ray must needs be the last that is visible, since it grazes the Earth, and another Ray, proceeding from the Sun above 18 Degrees under the Horizon, must needs be reflected above A, and be lost by the Eye placed in A. The Ray S S E C A, does then mark the End of the Crepuscle.

S S S, the Sun more than 18 Degrees under the Horizon, S S S, L, a Ray that goes and meets the Atmosphere at the Point L. It is partly admitted therein; the rest is reflected and lost in the Heaven. The small Part of it, which enters the thicker Air at L, instead of going directly to I, is bent a small Matter, grazes the Earth in I and goes to E, where it is partly lost in the Heaven, and partly reflected from E to D C; where it becomes totally insensible after so many Diminutions, and especially cannot reach the Eye in A, since the Angle of Reflexion D E F, being equal to the Angle of Incidence

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Incidence L E M, brings the remaining Part of the Ray to C, and not to A. The Light of the Crepuscule is then invisible, when the Sun is more than 18 Degrees under the Horizon ; and this Point is the End, as well as the Beginning of the Crepuscule.

Here we have made the Angles a great deal larger than they should be, to render the Effect of them much more sensible in a small Space. For, to reduce them to their exact Measure, we ought to have put the Semi-diameter A T forty Times larger than A B the Height of the Atmosphere, which would have rendered the Figure too large in Proportion to the Size of this Volume.

P A G E S 191, and 192.

The two Semi-planispheres, intituled, *the first and second Half of the Northern Celestial Hemisphere*, Pag. 191, and 192, represent together, as in a concave Vault, the Constellations dispersed in that Part of the Heaven round the Arctic Pole to the Æquator. Being divided, they burden the Book much less, and may equally help us to follow the Order of the Stars. The other two Halves, Pag. 193, and 194, represent the Constellations of the other Hemisphere, from the Æquator to the Southern Pole, which is the Centre of it. So soon as we are sure of knowing one single Constellation, or even a single Star, as for Instance, the Polar, which is very near the Arctic Pole, in a fine Night we may, by comparing the neighbouring Stars that are in the Planispheres, with those we perceive in the Heaven, by Degrees distinguish the latter, and call the principal of them by their Names. As to the Origin of these Names and Figures, see the first Vol. of the *History of the Heavens*. The Planispheres we here give are drawn after those of Dr. Halley, F. R. S.

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